TCVN **VIETNAM NATIONAL STANDARD**

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Second edition

CONCRETE AND REINFORCED CONCRETE STRUCTURE. DESIGN STANDARD

(This translation is for reference only)

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Information Center for Standards, Metrology and Quality- 8 Hoang Quoc Viet Street, Cau Giay, Hanoi, Vietnam, Tel: 844 37562608.

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Foreword

TCVN 5574:2012 replaces TCVN 5574:1991.

TCVN 5574:2012 was converted from TCXDVN 356:2006 into Vietnam National Standard under the regulation specified in Clause 1, Article 69 of the Law on Standards and Technical Regulations and Clause 1, Article 6 of Decree No. 127/2007/ND-CP dated 1/8/2007 of the Government detailing the implementation of a number of articles of the Law on Standards and Technical Regulations.

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CONCRETE AND REINFORCED CONCRETE STRUCTURE. DESIGN STANDARD

1. Scope

1.1. This standard replaces TCXDVN 356:2005.

1.2. This standard covers the design of concrete and reinforced concrete structures of buildings and works with different uses, bearing systematical effect of temperature in the range is not more than 50^{o}C and not less than -70^{o}C.

1.3. This standard specifies requirements relating to design of concrete and reinforced concrete structures made form heavy concrete, light-weight concrete, fine concrete, cellular concrete, hollow concrete as well as self-stressed concrete.

1.4. The requirements specified in this standard do not apply for: concrete and reinforced concrete structures used for public hydraulic structures, bridges, traffic tunnels, underground conduits, motor-road and airport pavements, steel-mesh cement structure, as well as for the structures made of concrete with average specific mass is less than 500 kg/m^3 and more than 2500 kg/m^3, polymer concrete, concrete having lime-slag agglutinant and mixed agglutinant (except when using mentioned above agglutinants in honeycombing concrete), concrete using gypsum agglutinant and special agglutinant, concrete with special organic aggregate, and concrete having large porosity in structure.

1.5. When designing concrete and reinforced concrete structures used in special conditions (such as earthquakes, strong erosion environments, and in high humidity conditions, etc...), it should comply to supplement requirements of relative standards.

2. Normative reference

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

TCVN 197-2002 Metals. Method of tractional test;

TCVN 1651-2008 Hot-rolled steel for reinforcement of concrete;

TCVN 1691-1975 Manual arc-welded joints;

TCVN 2737:1995 Loads and actions. Design standard;

TCVN 3118:1993 Heavy weight concrete. Determination of compressive strength;

TCVN 3223:2000 Welding electrodes for welding of carbon and low alloyed steels.

TCVN 3909:2000 Welding electrodes for carbon and low alloyed steels. Test methods;

TCVN 4612:1988 System of building design documents. Reinforced concrete structures. Symbols and representation on drawings

TCVN 5572:1991 System of building design documents. Concrete and reinforced concrete structures. Production drawings;

TCVN 5898:1995 Building and civil engineering drawings. Bar scheduling;

TCVN 6084:1995 Building and civil drawings. Symbols for concrete reinforcement

TCVN 6284:1997 Steel for the prestressing of concrete (Part 1 – 5);

TCVN 6288:1997 Cold-reduced steel wire for the reinforcement of concrete and the manufacture of welded fabric

TCVN 9346:2012 Concrete and reinforced concrete structures. Requirements of protection from corrosion in marine environment

TCVN 9392:2012 Metal arc welding of steel for concrete reinforcement

3. Terms, units of measurement and symbols

3.1 Terms

This standard uses material characteristics, "Concrete compressive strength level" and "Concrete tensile strength level" respectively instead of "Concrete mark according to compressive strength" and "Concrete mark according to tensile strength" used in TCVN 5574:1991.

3.1.1 Compressive strength of concrete

Signed by B, is the average statistic value of instantaneous compressive strength, expressed in MPa, with probability is not less than 95%, that was determined on cube samples of standard dimensions (150mm x 150mm x 150mm) manufactured and maintained in standard condition and taken compression test at 28 days of age.

3.1.2 Tensile strength of concrete

Signed by B_t, is the average statistic value of instantaneous tensile strength, expressed in MPa, with probability is not less than 95%, that was determined on standard tensile samples manufactured and maintained in standard condition and taken tension test at 28 days of age.

3.1.3 Concrete grades classified by compressive strength

Signed by M, is concrete strength, calculated as average statistic value of instantaneous compressive strength, expressed in daN/cm^2, determined on cube samples of standard dimensions (150mm x 150mm x 150mm) manufactured and maintained in standard condition and taken compression test at 28 days of age.

3.1.4 Concrete grades classified by tensile strength

Signed by K, is concrete strength, calculated as average statistic value of instantaneous tension strength, expressed in daN/cm^2, determined on standard tension specimens manufactured and cured in standard condition and taken compression test at 28 days of age.

Interrelation between concrete compressive (tensile) strength levels and concrete marks according to compressive (tensile) strength is given in Annex A.

3.1.5 Concrete structure

Structures made from concrete unreinforced or reinforced according to design requirements that is not included in calculation.

3.1.6 Reinforced concrete structure

Structure made from concrete reinforced with load resistant reinforcement and constructive reinforcement. All calculation internal forces are effects resisted by concrete and load resistant reinforcement in the reinforced concrete structure.

3.1.7 Load bearing reinforcement

reinforcement arranged according to design.

3.1.8 Nominal reinforcement

Reinforcement arranged according to construction requirements without calculation.

3.1.9 Tensioned reinforcement

Reinforcement was pre-stressed in the structure manufacturing process after to be effected by working load.

3.1.10 Effective deep of section: is the distance from compressed edge of member to section centroid of tensioned longitudinal reinforcement.

3.1.11 Concrete cover

Concrete layer having thickness determined from member edge to the nearest surface of reinforcement bar.

3.1.12 Ultimate force

The biggest internal force that member and its section (with its select material characteristics) can resist.

3.1.13 Limiting state

The state when it is exceeded, the structure does not meet requirements of use defined when design.

3.1.14 Normal service condition

The use condition complying with the requirements that have been calculated before according to standards or in design, meeting the requirements on technology as well as application.

3.2 Measurement units

SI units shall be used in this standard. Length Unit: m; stress unit: MPa; force unit: N (Unit converting table is given in Annex G).

3.3. Symbols and parameters

3.3.1 Geometrical characteristics

b- width of rectangular cross section; width of the frame of T and I sections;

b_f, b'_f - width of the wing of T and I sections in tensioned and compressed zones, respectively;

h- the height of rectangular, T and I sections;

h_f, h'_f - the height of the wings of T and I sections in tensile and compressed zones, respectively;

a, a'- the distance from combined force in the reinforcement corresponding to S and S' to the nearest margin of the section;

h_0, h'_0 - working height of sections, equal to h-a and h-a', respectively.

x- the height of compressed concrete zone;

ξ - the relative height of compressed concrete zone; equal to x/h_0;

s- the distance between stirrups along the member;

e_0- eccentricity of longitudinal force N to centroid of conversion section, determined according to the instruction given in 4.2.12;

e_{0p}- eccentricity of precompression force P to centroid of conversion section that is determined according to the instruction given in 4.3.6;

$e_{0,tot}$- eccentricity of combination force between longitudinal force N and precompression force P to the centroid of conversion section;

e, e'- correlative distances from the point of longitudinal force N to combination forces in reinforcement S and S', respectively;

e_s, e_{sp}- correlative distances from point of longitudinal force N and compressive force P to the centroid of reinforcement S;

l - member span;

l_0- design length of member sustaining longitudinal compression force; values of l_0 are given in Table 31, Table 32 and Subclause 6.2.2.16;

i- inertia radius of member's cross section with section centroid;

d- nominal diameter of reinforcement bar;

A_s, A'_s - respectively are sectional areas of un-tension reinforcement S and tension reinforcement S'; and when determining the front compression force P they are the sectional areas of un-strained reinforcements S and S', respectively;

A_{sp}, A'_{sp} - sectional areas of strained reinforcement S and S', respectively;

A_{sw} - sectional area of stirrup put in the plane perpendicular to member longitudinal axis and cutting through sloping section;

$A_{s, inc}$ - sectional area of oblique reinforcement bar put in the plane inclined to member longitudinal axis and cutting through sloping section;

μ- reinforcement content determined as the ratio between reinforcement sectional area S and cross sectional area of the member bh_0, that does not take into account the compressed and tensioned wings;

A- total cross sectional area of concrete;

A_b- sectional area of compressed concrete zone;

A_{bt}- sectional area of tensioned concrete zone;

A_{red} - conversion sectional area of member determined according to instruction given in 4.3.6;

A_{loc1}- area of locally compressed concrete;

S'_{b0}, S_{b0} - statistical moment of the respective sectional area of compressed and tensioned concrete zone to neutral axis;

S_{s0}, S'_{s0} statistical moment of the reinforce sectional area of S and S' to neutral axis;

I- inertia moment of concrete section to section centroid of the member;

I_{red}- inertia moment of conversion section to its centroid that is determined according to instruction given in 4.3.6;

I_s- inertia moment of reinforcement section to member section centroid;

I_{bo} - inertia moment of compressed concrete section to neutral axis;

I_{s0}, I'_{s0} - inertia moment of the respective reinforce section S and S' to neutral axis;

W_{red} - anti-bend moment of conversion section of the member to compressed boundary fibre, it is determined the same as elastic materials according to instruction in 4.3.6.

3.3.2 Requirements for reinforcement positions in cross section of the members

S is symbol of longitudinal reinforcement:

- When existing both concrete section zones to be compressed and tensioned due to external force effects; S expresses the reinforcement in tensioned zone;

- When total concrete is compressed: S expresses the reinforcement at the margin to be compressed more slightly;

- When the total concrete is tensioned :

+ For the members is tensioned eccentrically: it expresses the reinforcement at margin to be tensioned more strongly;

+ For the members is tensioned centrically: it expresses the reinforcement put all over the cross section of the member;

S'- is the symbol of longitudinal reinforcement:

- When existing both concrete section zones to be compressed and tensioned due to external force effect; S' expresses the reinforcement in compressed zone;

- When total concrete zone is compressed: it expresses the reinforcement at the margin to be compressed more strongly;

- For the members tensioned eccentrically, when total concrete zones is tensioned , it expresses the reinforcement at margin is tensioned more strongly than the member.

3.3.3 External and internal forces

F Concentrated external force;

M Bending moment;

M_t Twisting moment;

N Longitudinal force;

Q Cutting force.

3.3.4. Material characteristics

R_b, $R_{b,ser}$ - design longitudinal compression strength of the concrete corresponds to first and second limit states.

R_{bn}- standard longitudinal compression strength of the concrete corresponds to first limit states (prism strength);

R_{bt}, $R_{bt,ser}$ - design longitudinal tension strength of the concrete corresponds to first and second limit states.

R_{bnt} -standard longitudinal tension strength of the concrete correspond to first limit states;

R_{bp} - the strength of concrete when starting to be prestressed;

R_s, $R_{s,ser}$ - design tension strength of reinforcement correspond to first and second limit states.

R_{sw}- design tension strength of horizontal reinforcement is determined according to the requirements of

Subclause 5.2.2.4;

R_{sc}- design compression strength of reinforcement corresponds to first and second limit state;

E_b- initial modulus of elastic of concrete when compressed and tensioned;

E_s - the initial elastic modulus of reinforcement.

3.3.5 . Characteristics of prestressed member

P- Pre-compression force, to be determined according to formula (8) including stress losses in the reinforcement correspond to each working phase of the members.

σ_{sp}, σ'_{sp} - are pre-stresses in reinforcements S and S' respectively before compressing concrete when tensioning reinforcement on base (pre-tensioned) or when the pre-stress values in concrete decreased to 0 by giving the member with real external force or invention external force. The real external force or invention external force shall be determined in accordance with the requirements given in 4.3.1 and 4.3.6, where the stress loss in reinforcement correspondent to each working step of the member shall be considered;

σ_{bp} - Compressive stress in concrete in pre-compression process is determined according to 4.3.6 and 4.3.7 including the stress loss in reinforcement correspondent to each working step of the member;

γ_{sp} - Coefficient of precision when tensioning the reinforcement, to be determined according to the requirements in 4.3.5.

4. General instruction

4.1. Basic principles

4.1.1. Calculation, constitution and determination of materials and sizes for concrete and reinforced concrete structures shall be done carefully so as to do not occur limiting states in them with required reliability.

4.1.2. When applying structure solution in particular execution condition, the selection of structure solution shall be originated from techno-economic reasonableness; including maximum decrease of material, energy, labour and cost by:

- Use effectively materials and structures;

- Reduce structure weight;

- Use absolutely physico-mechanical characteristics of material;

- Use in place materials.

4.1.3. When designing buildings and constructions, structure diagram making, section dimension selection and reinforcement arrangement shall be done in order to ensure durability, stability and spatial invariability in general or in parts of the structure in construction and using processes.

4.1.4. Fabricated members should be in accordance with mechanical production conditions in specialized factory.

When selecting member for precasted construction, priority must given to use of prestressing structure made of high-strength concrete and reinforcement, as well as the structures made from lightweight concrete and cellular concrete when there are not any limiting requirements in the relative standards.

It is needed to select and combine reinforced concrete members jointed suitably in accordance with production and transportation conditions.

4.1.5. For in place structures, unification of dimension should be concerned in order to use rotating formwork as well as use cages of space reinforcement produced according to modulus.

4.1.6. For joint structures, durability and lifetime of the joint is specially paid attention to.

Technology solutions and structures should be applied in such a way that structure of the joint can surely transmit force, assure the durability of these structures in the connection zone as well as assure the adhesion of the newly poured concrete into the old concrete of the structure.

4.1.7. Concrete member is used:

a) Majority in compressive structures with the eccentricity of the longitudinal force not exceeding the limit given in 6.1.2.2.

b) In some compressive structures with big eccentricity as well as bending structures in which its destruction does not directly cause danger to the man and intactness of the equipment (details on the continuous foundation...).

Note: Structure is considered concrete structure if its durability is assured by the concrete only in the process of use.

4.2. Basic calculation requirements

4.2.1. Reinforced concrete structure should satisfy the requirements on calculation according to durability (the first limit states) and meet normal use conditions (the second limit states).

a) Calculation according to the first limit states is for assuring the structures:

- Not in plastic and brittle failure or other damage forms (if necessary, calculation according to durability concerns deflection of the structure at the time before being damaged);

- Not to be lost stability on the form (stable calculation on thin wall structure) or on the position (calculation on antislip and upturn resistance for the soil retaining wall, calculation of antifloat or underground tanks, pumping station...);

- Not to be damaged due to fatigue (fatigue calculation for members or structures bearing action of the repeat load according to live or impulsive type for example girder beam, frame foundation, the floor with placing unbalanced machineries);

- Not to be damaged due to the simultaneous action of the force elements and bad effects of the environment (periodic or permanent action of the eroded environment or fire).

b) Calculation according to the second limit states is for assuring normal working of the structure so that:

- Not forming as well as excessively widening the crack or long term crack if the condition of use does not allow to form or widen long term crack.

- Not having deformations exceeding the permitted levels (deflection, angle of rotation, angle of slide and oscillation).

4.2.2. Calculation on the total of structure as well as calculation on each member should be made at all stages: manufacture, transportation, execution, use and repair. Calculation diagram corresponding to each period should be in accordance with the selected structure solution.

Deformation and widening crack is allowed not to be calculated if through experiment and reality of use, the similar structures have affirmed that the width of the crack at all stages does not exceed permitted values and structures are stiff enough at the stage of use.

4.2.3. When calculating the structure, value of the load and action, confidence factor, combination factor, load reduction factor as well as classification of permanent load and live load should be taken in accordance with the current standards on load and action.

Load concerned in the calculation according to the second limit state should be taken in accordance with requirements in 4.2.7 and 4.2.11.

Note 1: At the extremely hot regions in which structure is not protected, bearing solar radiation, thermal action should be concerned.

Note 2: For structures contacting to water (or lie in the water), back pressure of the water should be concerned (load taken according to design standard on hydraulic structure).

Note 3: Concrete structures and reinforced concrete structures should be assured to fire proof ability in accordance with current standards.

4.2.4. When calculating member of joint structures with concern of the supplementary internal force arising in the process of transportation and loading and unloading by crane , load due to the weight of its own member should be multiplied with the dynamics factor, taken equal to 1.6 when transporting and taken equal to 1.4 when loading and unloading by crane. For these above dynamics factors, if having solid basis, it is allowed to take lower values but not below 1.25.

4.2.5. Semi joint structures as well as jointless structure using load bearing reinforcement should be calculated according to durability, the crack forming and widening and according to deformation under the following working periods:

a) Before the newly poured concrete reaches regulated strength, the structure shall be calculated according to load due to weight of the newly poured concrete and of any other loads acting in the process of pouring concrete.

b) After the newly poured concrete reaches regulated strength, the structure shall be calculated according to load acting in the process of building and load when using.

4.2.6. Internal force in the super-statically reinforced concrete structure due to action of the load and compulsory displacement (due to changes of temperature, humidity of the concrete, displacement of the bearing...) as well as internal force in the statically determinate structures when calculating according to the diagram of the deformation are defined with the concern of plastic deformation of the reinforced concrete and with the concern of the appearance of the crack.

For structures in which the method of calculating internal force concerned plastic deformation of the unfinished reinforced concrete as well as in the intermediate calculation period for statically indeterminate structure with the concern of plastic deformation, it is allowed to define internal force according to the supposition of linear elastic working material.

4.2.7. Anticracking ability of structures and parts of the structures is classified into 3 classes depending on its working condition and types of the used reinforcement.

Class 1: Not allow to appear crack;

Class 2: Allow to have short term widening of the crack with limited width a_{crc1} but assuring that the crack is surely closed later;

Class 3: Allow to have short term widening of the crack with limited width a_{crc1} and long term widening of the crack with limited width a_{crc2}.

The width of short-term crack means the widening of the crack when the structures simultaneously bear action of permanent load, short term and long term load.

The width of the long-term cracks means the widening of the crack when the structures only bear permanent load and long term load.

Anticracking class of the reinforced concrete structures as well as the value of the allowable limited width of the crack in the environment uneroded condition is given in the table 1 (assuring to limit seepage for the structures) and table 2 (protecting safety for the reinforcement).

Table 1 – Anticracking class and width value of the limited crack for limiting the absorption of the structure

Working condition of the structure		Anticracking class and width value of the limited crack for limiting the absorption of the structure, mm	
1. Pressure structure of the liquid and gas	When the total of the section is tensile	Level 1*	$a_{crc1} = 0,3$ $a_{crc2} = 0,2$
	When the partial of the section is compressive	Level 3	
2. Pressure structure of bulk materials		Level 3	$a_{crc1} = 0,3$ $a_{crc2} = 0,2$
* Prestressed structure is prior to use. Only when having reliable basis, unprestressed structure with required anticracking class 3 is allowed to use			

Load used in the calculation of reinforced concrete structure according to the condition of forming, widening and closing the crack is taken according to table 3.

If in the structures or its parts requiring anticracking of the class 2 and 3 in which upon the action of the corresponding load given in table 3, the crack is not formed, it is not necessary to calculate according to the condition of widening the short-term crack and closing the crack (for class 2), or according to the condition of widening short-term and long-term crack (for class 3).

Requirements of anticracking class for the above reinforced concrete structures are applicable for perpendicular crack and oblique crack in comparison with longitudinal axis of the member.

In order to avoid widening longitudinal crack, it is necessary to have structure measures (for example: setting lateral reinforcement). For prestressed members, besides these above measures, it is necessary to limit compressive stress in the concrete in the period of concrete precompression (see 4.3.7).

4.2.8. At the ends of the prestressed members with the reinforcement without anchorage, it is not allowed to appear crack in the period of stress transmission (see 5.2.2.5) when the permanent, long term and short term load bearing member has the factor γ_f equal to 1.0.

In this case, prestress in the reinforcement in the period of stress transmission is considered to linearly increase from 0 to the maximum design value.

The above requirements are allowed not to be applied for the section from the conversion section centre to tensile border (according to the height of the section) when having action of the prestress if in this section not arrange tensile reinforcement without anchorage.

4.2.9. In case of when bearing action of use load according to the calculation in the compression zone of the prestressed member with the appearance of the crack perpendicular to the longitudinal axis of the component in the periods of production, transportation and assembly, anticracking ability of the tensile zone as well as the increase of the deflection in the process of use should be examined.

For members calculated to bear the action of the repeat load, the above cracks are not allowed to appear.

For reinforced concrete members with few reinforcement in which force bearing ability disappears at the same time with the forming of the cracks in the tensile concrete zone (see 7.1.2.8), the area of the section of the tensile longitudinal reinforcement should be increased by 15% in comparison with the required area of the reinforcement when calculating according to the durability grade.

Table 2- Anticracking class of the reinforced concrete structures and width value of the limited crack a_{crc1} and a_{crc2} for protecting safety of the reinforcement

Working condition of the structure	Anticracking class and values a_{crc1} and a_{crc2}, mm		
	Bar steel of CI, A-I, CII, A-II, CIII, A-III, A-IIIB, CIV A-IV Fibre steel of B-I vµ Bp-I	Bar steel of A-V, A-VI Fibre steel of B-II and Bp-II, K-7, K-19 with diameter not below 3.5 mm	Bar steel of AT-VII Fibre steel B-II vµ Bp-II and K-7 with diameter not exceeding 3.0 mm
1. At the covered place	Level 3 a_{crc1} = 0,4 a_{crc2} = 0,3	Level 3 a_{crc1} = 0,3 a_{crc2} = 0,2	Level 3 a_{crc1} = 0,2 a_{crc2} = 0,1
2. Outdoors or in earth's womb, over or below the underground water lever	Level 3 a_{crc1} = 0,4 a_{crc2} = 0,3	Level 3 a_{crc1} = 0,2 a_{crc2} = 0,1	Level 2 a_{crc1} = 0,2
3. In earth's womb with variable underground water level	Level 3 a_{crc1} = 0,3 a_{crc2} = 0,2	Level 2 a_{crc1} = 0,2	Level 2 a_{crc1} = 0,1

Note 1: Symbol of steel group, see ***5.2.1.1*** *and* ***5.2.1.9.***

Note 2: For cab le steel, regulations in this table are applicable to the extreme steel fibre.

Note 3: For structures using bar reinforcement of A-V group operating at cover placed or outdoors, when having experiences on the design or using these structures, the values a_{crc1} and a_{crc2} are allowed to increase by 0.1 mm in comparison with the value given in this table.

Table 3- Load and confidence factor on load

Anticracking class of the reinforced concrete structure	**Load and confidence factor γ_f when calculating according to the condition**			
	Forming crack	**Widening the crack**		**Closing the crack**
		Short-term	**Long- term**	
1	Permanent load; long term and short term temporary load with $\gamma_f > 1,0$*	–	–	–
2	Permanent load; long term and short term live load with $\gamma_f >1,0$* (calculated in order to clarify the necessity to check according to the condition of not widening the short term crack and closing them)	Permanent load; long term and short term live load with $\gamma_f > 1,0$*	–	Permanent load; long term live load with $\gamma_f = 1,0$*
3	Permanent load; long term and short term live load with $\gamma_f =1,0$* (calculated in order to clarify the necessity to check according to the condition of widening the crack)	As above	Permanent load; long term temporary load with $\gamma_f = 1,0$*	–

* The factor γ_f is taken similarly to calculate according to durability grade

Note 1: Long term and momentary load taken according to 4.2.3.

Note 2: Special load shall be concerned when calculating according to the condition of forming crack in case of the presence of the crack leading to dangerous state (explosion, fire...)

4.2.10 The sags and transposition of structure members shall not exceed permitted limits given in Annex C. The limiting sags of common members are given in Table 4.

4.2.11 When calculate according to endurance of the concrete and reinforced concrete members bearing impacts of longitudinal forces, random eccentricity e_a caused by unexpected factors in calculating must be noticed.

In all cases, the random eccentricity e_a shall be taken not less than:

- 1/600 length of members or distances between its sections that is transposition-blocked joint;

- 1/30 height of member sections;

Table 4. Limit sag level of common members

Kinds of members	Sag limits
1. Crane girder with:	
a) manual crane	1/500L
b) electric crane	1/600L
2. Floor with even ceiling, wall components and suspension wall sheet (when calculating wall sheet outside the plane	
a) when L < 6 m	(1/200) L
b) when 6 m ≤ L ≤ 7,5 m	3 cm
c) when L > 7,5m	(1/250)L
3. Floor with ceiling having side and stairs	
a) when L < 5 m	(1/200)L
b) when 5 m ≤ L ≤ 10 m	2,5 cm
c) when L > 10 m	(1/400)L
Note: L is span of girder or plate put on 2 pillows; for cantilever $L=2L_1$ where L_1 is extending length of cantilever. ***Note** 1: When designing the structures having front convexity, at the time of calculating sag, it is permitted to deduct mentioned -above front convexity if there is no special restriction.* ***Note** 2: When bearing effects of permanent loads, temporary long -term and short-term loads, the sag of girders or plates in all cases should not exceed 1/150 span or 1/75 of extending length of the cantilever.* ***Note** 3: When the limiting sags are not binded by the requirements of production technology and structure but the requirements of aesthetics only, to calculate the sag, you can take only long term loads. In this case, $\gamma_f = 1$.*	

In addition, for fabricated structures, the possible reciprocal transpositions of members shall be considered. These kinds of transposition are dependent on kinds of structure, putting-together methods, etc...

For the members of super statically structures, the eccentricity e_0 of longitudinal force to centroid of converting section shall be taken equal to the eccentricity determined from structure static analysis, but it must not be less than e_a.

In the members of super-statically structures, the eccentric e_0 shall be taken equal to sum of eccentricities taken from calculations of static and random eccentricity.

The distances between thermal-elastic slots shall be determined by calculations.

For common reinforced concrete structure and prestressed reinforced concrete structure, it requires anti-fissure grade 3 and permits not to calculate distance mentioned above if it does not exceed values given in Table 5.

Table 5. Permitted maximum distance between thermal-elastic slots, no calculation

Dimension in m

Structures			**Working conditions of the structures**		
			In land	**In house**	**Outside**
Concrete	Fabricated frames		40	35	30
	Whole block	With constructive steel arrangement	30	25	20
		Without constructive steel arrangement	20	15	10
Reinforced concrete	Fabricated frames	One-storey buildings	72	60	48
		Multi-storey buildings	60	50	40
	Semi-fabricated frames or whole block		50	40	30
	Whole block condensed or semi-fabricated structures		40	30	25

Note 1: The values given in this table do not apply for structures with temperature resistance less than –40°C.

Note 2: For the structure of one-storey buildings, permit to increase the values given in table 5 by 20%.

Note 3: For frame building, the values showed in this table agree to frames without column bracing system or when bracing system to be put in the center of temperature block.

4.3 Addition requirements when designing prestressed reinforced concrete structure

4.3.1 Corresponding prestress values σ_{sp}, σ'_{sp} to tensile reinforcement S and S' shall be chosen with deviation p in such a way that it satisfies the following requirements:

$$\sigma_{sp}\ (\sigma'_{sp}) + p \le R_{s,ser} \qquad (1)$$

$$\sigma_{sp}\ (\sigma'_{sp}) - p \ge 0{,}3\ R_{s,ser}$$

Where: P expressed in MPa, to be determined as follow:

- In case of weighing to be done by mechanical method: $p = 0{,}05\,\sigma_{sp}$;

- In case tension is implemented by thermo-electric and mechanic-thermal electric methods:

$$p = 30 + \frac{360}{l} \qquad (2)$$

Where: l – is the length of tensile reinforcement bar (the distance between outside edges of the base), mm.

In case tension is implemented by automated devices, the numerator value of 360 in the formula 2 shall be change into 90.

4.3.2 The corresponding stress values σ_{con1} and σ'_{con1} in tensioned reinforcement S and S' controlled after tensioning on base shall be taken as σ_{sp} and σ'_{sp} respectively (see Subsclause 4.3.1) minus losses caused by anchor deformation and reinforcement friction (see Subsclause 4.3.3).

Stress values in tensioned reinforcements S and S' is controlled at the position putting tensile forces when tensioning the reinforcements on hard concrete is taken correspondingly as σ_{con1} and σ'_{con2}, Where σ_{con2} and σ'_{con2} were determined from the conditions to ensure stress σ_{sp} and σ'_{sp} in calculation section. Then, σ_{con2} and σ'_{con2} shall be determined as the following formulas:

$$\sigma_{con2} = \sigma_{sp} - \alpha\left[\frac{p}{A_{red}} + \frac{Pe_{0p}y_{sp}}{I_{red}}\right] \qquad (3)$$

$$\sigma'_{con2} = \sigma'_{sp} - \alpha\left[\frac{p}{A_{red}} + \frac{Pe_{0p}y'_{sp}}{I_{red}}\right] \qquad (4)$$

In the formulas (3) and (4):

σ_{sp}, σ'_{sp} - determined without concerning stress losses;

P, e_{0p} - determined according to (8) and (9), where σ_{sp} and σ'_{sp} is determined including first stress losses;

y_{sp} and y'_{sp} - see Subclause 4.3.6;

$\alpha = E_s/E_b$.

The stress in self -stressed reinforcements is calculated from the balanced conditions with stress (self - stressed) in the concrete.

Self-causing stress of concrete in the structure determined according to concrete mark in accordance with self-causing stress ability S_p including reinforcement content, arrangement of reinforcements in concrete (1 axis, 2 axis, 3 axis), as well as in the necessary cases, it is needed to include stress loss caused by shrinkage and concrete magnetization when the structure bearing a load.

Note: *In the structures made from lightweight concrete with grades from B 7.5 to B 12.5, the values of* σ_{con2} *and* σ'_{con2} *should not exceed the corresponding values of 400 MPa and 550 MPa.*

4.3.3 When calculating pre-stressed members, it should include the pre-stressed losses in reinforcements when it is tensioned:

- When tensioning on base, the following factors must be concluded:

+ First losses: due to anchor deformation, reinforcement friction with direction setting equipment, stress loosen in reinforcement, temperature change, mould deformation (when stretching reinforcement on mould), due to rapid magnetization of the concrete.

+ Second losses: due to shrinkage and magnetization of concrete.

- When tensioning on concrete, it is needed to consider:

+ First losses: due to anchor deformation, reinforcement friction with steel (cable) putting pipe or with concrete surface of the structure.

+ Second losses: due to stress slackening in reinforcement, due to shrinkage and magnetization of the concrete, local compression of reinforcement rings on concrete surface, deformation of joints between concrete blocks (for structure joined from blocks).

Stress losses in reinforcement are determined according to Table 6, but the sum of stress losses shall be not less than 100 MPa.

When calculating self-stressed members, stress losses due to shrinkage and magnetization of concrete depending on mark of self-prestressed concrete and environment humidity shall be concluded only.

For self-stressed structures in water saturated conditions, stress losses due to shrinkage shall not be considered.

Table 6. Stress loss

Factors causing prestressed losses in reinforcement	**Stress loss values, MPa**	
	When tensioning on base	**When tensioning on concrete**
A. ***First losses***		
1. Stress type in reinforcement		
- When tensioning by mechanical methods		
a) For fibre steel	$\left(0{,}22\dfrac{\sigma_{sp}}{R_{s,ser}}-0{,}1\right)\sigma_{sp}$	-
b) For bar steel	$0{,}1\sigma_{sp}-20$	-
- When tensioning by thermoelectric and mechanic-thermal electric methods		
a) For fibre steel	$0{,}05\sigma_{sp}$	-
b) For bar steel	$0{,}03\sigma_{sp}$	-
	Where: σ_{sp} , MPa, determined not including stress losses. If value of stress loss taken "minus" mark, will be 0.	

Table 6 (continued)

Factors causing prestressed losses in reinforcement	Stress loss values, MPa	
	When tensioning on base	When tensioning on concrete
2. Temperature difference between tensile reinforcement in burned zone and tensile-receiving equipment when concrete is burned	For concrete from grade B15 to B40:: $1{,}25\,\Delta t$ For concrete grade B45 and over: $1{,}0\,\Delta t$ Where: Δt - temperature difference between burned reinforcement and fix tensile bed (outside the burned zone) receiving tensile force, 0C. When lacking of exact data, $\Delta t = 65^{o}C$. When tensioning reinforcement in heating process to numeric value enough to cover stress loss due to temperature difference, stress loss due to temperature difference is taken zero.	- -
3. Deformation of anchor at tensile equipment.	$\frac{\Delta l}{l} E_s$ where: Δl deformation of compression rings, partial compression anchor head, are taken 2mm; when there are slipping between reinforcement bars in press equipment that used many times, Δl is defined as follows: $\Delta l = 1{,}25 + 0{,}15\,d$ where: d – diameter of reinforcement bar, mm; l - length of tensile reinforcement (space between outer edge of cushion on bed of mould or equipment), mm. When stretching by thermoelectricity, loss due to anchor deformation is excluded in calculation because they are included in determining full stretch of the reinforcement	$\frac{\Delta l_1 + \Delta l_2}{l} E_s$ where: Δl_1 - deformation of screw nut or cushion plates between anchor and concrete, is taken 1 mm; Δl_2 - deformation of tumbler anchor, screw nut anchor, is taken 1 mm. l - length of tension reinforcement (1 fiber), or member, mm

Table 6 (continued)

Factors causing prestressed losses in reinforcement	Stress loss values, MPa	
	When tensioning on base	When tensioning on concrete
4. Friction of reinforcement		
a) With gutter wall or surface of concrete		$\sigma_{sp}\left(1-\frac{1}{e^{\omega\chi+\delta\theta}}\right)$ where: e - natural logarithm base; δ, ω - factors, defined as in Table 7; χ - height from tensile equipment to calculated section, m; θ - total change direction angle of reinforcement axis, radian; σ_{sp} - is taken not including stress loss..
b) With direction setting equipment	$\sigma_{sp}\left(1-\frac{1}{e^{\delta\theta}}\right)$ where: e - natural logarithm base; δ - factors, taken by 0,25; θ - total change direction angle of reinforcement axis, radian; σ_{sp} - is taken excluded stress loss.	
5. Deformation of steel mould when fabricating prestressed reinforcement concrete structure	$\eta\frac{\Delta l}{l}E_s$ where: η – factor, taken as: + $\eta=\frac{n-1}{2n}$, when tensioning inforcement by jack; + $\eta=\frac{n-1}{4n}$, when tensioning reinforcement by electro thermal- mechanical method using winch (50% force caused by load of heavy object).	–

Table 6 (continued)

Factors causing prestressed losses in reinforcement	**Stress loss values, MPa**	
	When tensioning on base	**When tensioning on concrete**
	n - number of reinforcement group stretched not at the same time. Δl - space moving near each other of cushions on bed according to effect direction of force P, is determined from mould deformation calculation. l - space between outer edge of cushion on tension bed. When lacking of data on fabrication technology and mould structure, loss due to mould deformation taken 30 MPa. With electro-thermal stretch, losses due to mould deformation in calculation are not included because they are mentioned in determining full elongation of reinforcement.	
6. Fast creep of concrete		
a) For natural hardened concrete	$40\frac{\sigma_{bp}}{R_{bp}}$ when $\frac{\sigma_{bp}}{R_{bp}} \leq \alpha$ $40\alpha + 85\beta\left(\frac{\sigma_{bp}}{R_{bp}} - \alpha\right)$ when $\frac{\sigma_{bp}}{R_{bp}} > \alpha$ Where: α vµ β - factors, taken as follows: α = 0,25 + 0,025 R_{bp}, but not exceed 0,8; β = 5,25 - 0,185 R_{bp}, but not exceed 2,5 and lower than 1,1; σ_{bp} - determined at center point level of longitudinal reinforcement S and S', including loss according to items from 1 to 5 in this table. The strength at the time of prestress beginning is 11 MPa or less than, coefficient 40 is replaced by 60 for light concrete	
b) For thermal curing concrete	Loss calculated according to equation in item 6a of this table, then multiply with coefficient 0.85	

Table 6 (continued)

Factors causing prestressed losses in reinforcement		Stress loss values, MPa		
		When tensioning on base		When tensioning on concrete
B. Second losses				
7. Stress relaxation in reinforcement				
a) For fiber steel		-		$\left(0{,}22\dfrac{\sigma_{sp}}{R_{s,ser}}-0{,}1\right)\sigma_{sp}$
b) For bar steel		-		$0{,}1\sigma_{sp}-20$ (see annotate for item 1 in this table)
8. Concrete shrinkage (see subclause 4.3.4)		Natural hardened concrete	Thermal curing concrete in Atmosphere pressure condition	Not depend on hardening concrete condition of the concrete
Heavy-weighted concrete	a) B35 and lower	40	35	30
	b) B40	50	40	35
	c) B45 and over	60	50	40
Small particle concrete	d) group A	Loss is determined according to item 8a, b in this table and multiply with coefficient 1.3		40
	e) group B	Loss is determined according to item 8a in this table and multiply with coefficient 1.5		50
	f) group C	Loss is determined according to item 8a in this table, the same with natural hardened heavy concrete		40
Light concrete with fine aggregate	g) Solid type	50	45	40
	h) porous type	70	60	50
9. Creep of concrete (see subclause 4.3.4)				
a) For heavy concrete and light concrete with fine, hard aggregate		$150\alpha\sigma_{bp}/R_{bp}$ when $\sigma_{bp}/R_{bp}\le 0{,}75$; $300\alpha(\sigma_{bp}/R_{bp}-0{,}375)$ when $\sigma_{bp}/R_{bp}>0{,}75$, where: σ_{bp} - taken as item 6 in this table; α - coefficient, taken as follows: + with natural hardened concrete, α = 1; + with thermal curing concrete in atmosphere pressure condition, α = 0,85.		

Table 6 (the end)

<table>
<tr><th colspan="2" rowspan="2">Factors causing prestressed losses in reinforcement</th><th colspan="2">Stress loss values, MPa</th></tr>
<tr><th>When tensioning on base</th><th>When tensioning on concrete</th></tr>
<tr><td rowspan="3">b) Small particle concrete</td><td>group A</td><td colspan="2">Loss is calculated according to equation in item 9a of this table , then multiply result with coefficient 1.3</td></tr>
<tr><td>group B</td><td colspan="2">Loss is calculated according to equation in item 9a of this table, then multiply result with coefficient 1.5</td></tr>
<tr><td>group C</td><td colspan="2">Loss is calculated according to equation in item 9a of this Table, α = 0,85</td></tr>
<tr><td colspan="2">c) Light concrete used fine, porous aggregate</td><td colspan="2">Loss is calculated according to equation in item 9a of this table, then multiply result with coefficient 1.2</td></tr>
<tr><td colspan="2">10. Compressed partially concrete surface due to torsion type or round type of reinforcement (when diameter of structure is less than 3m)</td><td>-</td><td>70 - 0,22 d_{ext}
where: d_{ext} - outer diameter of structure, cm</td></tr>
<tr><td colspan="2">11. Compression deformation due to joint between blocks (for structure setting from blocks)</td><td>-</td><td>$n\frac{\Delta l}{l}E_s$
where: n - quantity of joint between structure and other equipment according to the length of tensile reinforcement;
Δl - deformation pressing against each joints:
+ with concrete filled joint Δl = 0,3 mm;
+ with direct joint, Δl = 0,5 mm;
l - length of tensile reinforcement, mm.</td></tr>
<tr><td colspan="4">Note 1: Stress loss in tensile reinforcement S' is specified similarly to the reinforcement S;
Note 2: For self-stressed reinforcement concrete structure, loss due to shrinkage and creep of concrete is determined according to experimental data.
Note 3: Stability level symbol of concrete see 5.1.1.</td></tr>
</table>

4.3.4. When determining stress loss due to shrinkage and creep of concrete according to subclause 8 and 9 in table 6, it should be noted:

a) When loading period on structure is known in advance, stress loss should multiply with coefficient φ_1, determined as follows:

$$\varphi_1 = \frac{4t}{100+3t} \quad (5)$$

Where:

t – time calculated by day, is determined as the following:

- When determining stress loss due to creep: calculate from day of compressing concrete;

- When determining stress loss due to shrinkage: calculate from finish-day of pouring concrete.

b) For structure in condition atmosphere humidity below 40%, stress loss should increase 25%. In the case structure made from heavy concrete, small particle concrete, working in hot climate zone and not protected from solar radiation, stress loss should increase 50%.

c) If type of cement, concrete component, fabricating condition and structure use are known clearly, more exact methods are allowed using to determine stress loss when that method is proved that having base according to temporary regulations.

Table 7. Coefficients to determine stress loss due to reinforcement friction.

Gutter or contact surface	Coefficients to determine loss due to reinforcement friction (see item 4, table 6)		
	ω	δ when reinforcement is	
		steel bundle or fiber	bar with edge
1. Gutter type			
- metal surface	0.0030	0.35	0.40
- concrete surface made from hard core mould	0	0.55	0.65
- concrete surface made from soft core mould	0.0015	0.55	0.65
2. Concrete surface	0	0.55	0.65

4.3.5. Pre-stress value in reinforcement for calculation should multiply with accuracy coefficient when straining reinforcement γ_{sp}:

$$\gamma_{sp} = 1 \pm \Delta\gamma_{sp} \quad (6)$$

In equation (6), "plus" mark is used if having disadvantage effect of pre-stress (it means that in particular working period of structure or a considering part of structure, pre-stress decreases force ability, foster crack forming, etc...); 'minus' mark is used for advantage effect.

In the case of creating pre-stress by mechanical method, value $\Delta\gamma_{sp}$ is taken 0.1; when strained by electro-thermal method and electro-thermal-mechanical method, $\Delta\gamma_{sp}$ is determined by the following equation:

$$\Delta\gamma_{sp} = 0.5 \frac{P}{\sigma_{sp}}(1+\frac{1}{\sqrt{n_p}} \qquad (7)$$

But taking not less than 0.1;

In equation (7):

p, σ_{sp} – see subclause 4.3.1;

n_p – number of tensile reinforcement bar in member section.

When determining stress loss in reinforcement, as well as when calculating in accordance with crack widening condition and deformation, allow taking zero for value $\Delta\gamma_{sp}$.

4.3.6. Stress in concrete and reinforcement, as well as pre-compression force in concrete used to calculate pre -stress concrete structure is determined by the following instruction:

Stress in the section perpendicular to member longitudinal axis is determined according to principles of calculating elastic materials. In which, calculation section is the corresponding section included concrete section with reduction due to gutters and section area of longitudinal reinforcement (tensile and intensile) multiplying with coefficient α in which α is ratio between elastic module of reinforcement E_s and concrete E_b. When there are many difference kinds and durability levels of concrete on section, stress should be converted into one kind or one level basing on their elastic module ratio.

Pre-compression stress P and its eccentric level e_{0p} in comparison with the center point of converted section are determined as follows:

$$P = \sigma_{sp}A_{sp} + \sigma'_{sp}A'_{sp} - \sigma_s A_s - \sigma'_s A'_s \qquad (8)$$

$$e_{0p} = \frac{\sigma_{sp}A_{sp}y_{sp} + \sigma'_s A'_s y'_s - \sigma'_{sp}A'_{sp}y'_{sp} - \sigma_s A_s y_s}{P} \qquad (9)$$

Where:

σ_s and σ'_s- stress in intensile reinforcement S and S' caused by shrinkage and creep in concrete, respectively;

y_{sp}, y'_{sp}, y_s, y'_s - spaces from the center point of converted sections to resultant force points of internal force in tensile reinforcement S and intensile reinforcement S' (Figure 1); respectively;

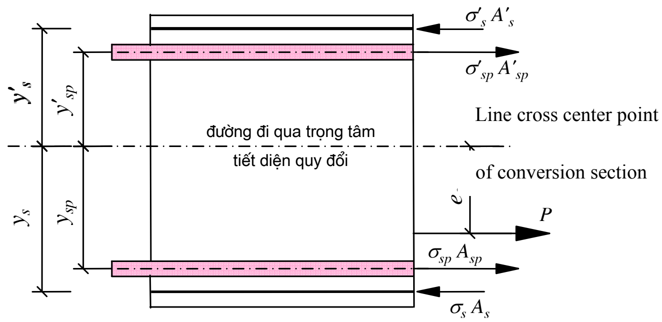


Figure 1: Pre-compression in reinforcement on transversal section of reinforce concrete member.

In the case tensile reinforcement has curved form, values σ_{sp} and σ'_{sp} should multiply with $\cos\theta$ and $\cos'\theta$, with θ and θ' being the inclined angle of reinforcement axis with member longitudinal axis (at considering section).

Stresses σ_{sp} and σ'_{sp} taken as follows:

a) In the stage of concrete pre -compression: include the first losses.

b) In the stage of using: include the first and second losses.

Value of stresses σ_s, σ'_s is taken as follows:

c) In the stage of concrete pre -compression: taken equal to stress loss due to fast creep according to item 6 of table 6.

d) In the stage of using: taken equal to the total of stress losses due to shrinkage and creep of concrete according items 6, 8 and 9 of table 6.

4.3.7. Concrete compression stress σ_{bp} in the stage of concrete pre-compression should satisfy the condition: Ratio σ_{bp} / R_{bp} are not greater than values in table 8.

σ_{bp} is determined at extreme compression fiber lever of concrete with loss according to item from 1 to 6 of table 6 and accuracy coefficient when straining reinforcement $\gamma_{sp} = 1$

Table 8. Ratio between compression stress in concrete σ_{bp} at pre -stress period and concrete strength R_{bp} when begin to bear pre -stress (σ_{sp} / R_{bp})

Stress state of section	Reinforcement tension method	Ratio σ_{sp} / R_{bp} not greater than	
		centric compression	eccentric compression
1. Stress is decreased or unchanged when structure bears external force	On bed (bonded)	0.85	0.95*
	On concrete (unbonded)	0.70	0.85
2. Stress is strained when structure bears external force	On bed (bonded)	0.65	0.70
	On concrete (unbonded)	0.60	0.65

Implement for members manufactured according to compression force regularly increasing condition, when there are steel connection parts at support and indirect reinforcement that steel content according to volume $\mu_v \geq 0,5\%$ (see subclause 8.5.3) is not less than the length of stress transmitting part l_p (see subclause 5.2.2.5), take value $\sigma_{bp}/R_{bp} = 1,0$.

Note: For light concrete grade from B7.5 to B12.5 value σ_{bp}/R_{bp} should take not greater than 0.3.

4.3.8. For prestressed structure that anticipate to adjust compressed stress in concrete in using process (e.g: in reactors, containers, television tower), using non-adherent tensile reinforcement, should have effective method to protect reinforcement from erosion. For non-adherent prestressed structure, should calculate according to requirements of 1st level anti-crack ability.

4.4. General principle for calculating plane structures and large block structures should include nonlinear characteristics of reinforcement.

4.4.1. Calculation of concrete structure and reinforcement concrete system (linear structure, plane structure, space structure and large block structure) with the first and the second limit states shall be applied in accordance with stress, internal force, deformation and transposition. Factors such as stress, internal force, deformation and transposition should be calculated from effect of external force on above structures (forming structure system of house and building) and should mention to physical non-linear characteristic, non-isotropy and in some necessary cases including creep and false agglomeration (in a long process) and geometric non-linear characteristic (major in thin wall structure).

Note: Non-isotropy is the difference on characteristics (mechanical characteristics) according to different directions. Ortho direction is one kind of non-isotropy, in which the difference in characteristics is in accordance with directions belonging to three symmetrical planes perpendicular to each other in couple.

4.4.2. Physical non-linear characteristics, non-isotropy and creep characteristics in interrelations determined in stress-deformation relation, as well as in strength condition and anti-crack condition of materials should be mentioned. At that time two deformation period of member should be divided: pre-crack forming and post-crack forming.

4.4.3. Before forming crack, use orthodirection non-linear model for concrete. This model allows mention to directive development of expansion effect and inhomogeneity of compression and tensile deformation. Nearly isotropic model of concrete shall be allowed to use. This model mention to the appearance of above factors according to three directions. For reinforced concrete, this period calculation should come from simultaneous deformation according to longitudinal direction of reinforcement and concrete part around themselves, excluding the end of reinforcement without specific anchorage.

When there is reinforcement widening danger, restrict limit compression stress value.

Note: Expansion is the volume increase of objects when compressed due to the development of microcrack as well as crack with considerable length.

4.4.4. According to strength condition of concrete, should mention to stress combination in different directions, because two-axis and three-axis compression strength are greater than one-axis ones. When bearing compression and tension at the same time, that strength is lower when concrete bearing only compression or tension. In necessary cases, it should pay attention to long term of effective stress.

Strength condition of reinforced concrete without crack should be specified in the base of strength condition of components materials when consider reinforced concrete as two components environment.

4.4.5. Take strength condition of concrete in two components environment as a condition of forming crack.

4.4.6. After appearing crack, should use general non-isotropy object model in non-linear relation between internal force or stress and displacement including the following factors:

- Inclined angle of crack in comparison with reinforcement and crack outline;

- Crack widening and slide of crack edge;

- Reinforcement hardness:

+ According to longitudinal axis: including agglutinate of reinforcement with strip or concrete segment among cracks;

+ According to tangent direction with crack edge: including tender of concrete at crack edges and longitudinal stress and tangent stress corresponding in reinforcement at crack;

- Concrete hardness:

+ Between cracks: including longitudinal force and slide force of concrete between cracks (in cross crack outline, this hardness is decreased);

+ At cracks: including longitudinal force and slide force of concrete at cracks;

- The disappearance of concurrence partially of longitudinal deformation of reinforcement and concrete between cracks.

In deformation model non-reinforced member with crack, only mention to hardness of concrete in the middle space of cracks.

In the cases appear inclined cracks, should mention to private characteristic of concrete deformation in the zone above cracks.

4.4.7. The width of crack and relatively slide transfer of crack edge should be determined in the base of transfer in different direction of reinforcement bars in comparison with crack edges cross them, mention to space among cracks and concurrent transfer condition.

4.4.8. Strength condition of plane member and large block structure with crack should be determined by the following suppositions:

- Ruining by considerable elongation reinforcement at most dangerous cracks, inclined with reinforcement bar and concrete break of strip or block among cracks or outside cracks (e.g: at compression zone of plate on cracks);

- Compression strength of concrete is decreased by tensile stress arising from cohesion force between concrete and normal tensile reinforcement, as well as transversal transfer of reinforcement near crack edge;

- When determining concrete strength, should mention to crack forming outline and inclined angle of crack in comparison with reinforcement;

- It is necessary to concern nominal stress in the reinforcement bar towards the longitudinal axis of the reinforcement. It is allowed to concern tangential stress in the reinforcement at the position having crack (angel effect), claiming that reinforced bars do not change direction;

- At damaged crack, reinforced bars cutting through reaching design tensile strength (for reinforcement without yield limit, stress should be checked in the process of deformation calculation).

Concrete strength at different zones shall be assessed according to stresses in the concrete as in the one part of the environment of two parts (not concerning conversion stress in the reinforcement among cracks defined with the concern of stress at cracks, adhesion and partially loosing the simultaneity of the longitudinal axis deformation of the concrete to the reinforcement).

4.4.9. For reinforced concrete structures able to bear plastic deformations, it is allowed to define its force bearing ability by the limit balance method.

4.4.10. When calculating according to durability, deformation, forming and widening crack according to the finite element method, it is necessary to check condition of durability, anticracking of all elements of the structure as well as check condition of appearing excess deformation of the structure.

When assessing limit state according to durability, some damaged elements are allowed if they do not cause the next damages of the structure and after the examining load stops acting, structure is still normally used or can be restorable.

5. Materials for concrete and reinforced concrete structures

5.1 Concrete

5.1.1. Classification of concrete and scope of usage

5.1.1.1. This standard is applicable for the following concretes:

- Heavyweight concrete with average volume from 2200 kg/m^3 to 2500 kg/m^3;

- Small particle concrete with average volume exceeding 1800 kg/m^3;

- Lightweight concrete with solid and hollow structures;

- Distillation and undistillation cellular concrete

- Special concrete: self-stressed concrete.

5.1.1.2. Depending on usage and working condition, when designing concrete and reinforced concrete structures, it is necessary to designate quality norms of the concrete. The main norms are as follows:

a) Compressive durability level B;

b) Axial tensile strength level B_t (designation in this specific case is of decisive importance and inspected during the process of production);

c) Marks according to anticorrosion ability, signed by W (designated for structures with seepage limit requirements);

d) Marks according to average volume quantity D (designated for structures with thermal-resistant requirements);

e) Marks according to self -stressed ability (designated for self-stressed structures when this characteristics is concerned in design and need to be inspected during the process of production).

Note 1: Compressive durability and axial tensile strength level, MPa should satisfy volume value with accuracy probability of 95 percent.

Note 2: Self -stressed concrete mark according to self-stressed ability is the prestressed value in concrete, MPa, caused by concrete being self -swelled, corresponding to longitudinal steel content in concrete of $\mu = 0{,}01$.

Note 3:. For facilitating the usage in reality, besides the designation of concrete level, concrete mark can be further noted in blankets. For example B30 (M400).

5.1.1.3. For concrete and reinforced concrete structures, usage of concretes with levels and marks is given in the table 9:

Table 9. Regulations on using grades and marks of concrete

Method of classification	Type of concrete		Grade or mark
According to compressive durability	Heavy concrete		B3,5; B5; B7,5; B10; B12,5; B15; B20; B25; B30; B35; B40; B45; B50; B55; B60
	Self-stressed concrete		B20; B25; B30; B35; B40; B45; B50; B55; B60
	Small particle concrete	Group A: Self hardening or curing in the atmosphere pressure condition, and aggregate with magnitude modulus exceeding 2.0	B3,5; B5; B7,5; B10; B12,5; B15; B20; B25; B30; B35; B40
		Group B: Self-hardening or curing in the atmosphere pressure condition, sand aggregate with magnitude modulus below or equal to 2.0	B3,5; B5; B7,5; B10; B12,5; B15; B20; B25; B30; B35
		Group C : Distilled	B15; B20; B25; B30; B35; B40; B45; B50; B55; B60
	Light aggregate concrete with mark according to average volume mass	D800, D900	B2,5; B3,5; B5; B7,5;
		D1000, D1100	B2,5; B3,5; B5; B7,5; B10; B12,5
		D1200, D1300	B2,5; B3,5; B5; B7,5; B10; B12,5; B15
		D1400, D1500	B3,5; B5; B7,5; B10; B12,5; B15; B20; B25; B30
		D1600, D1700	B5; B7,5; B10; B12,5; B15; B20; B25; B30; B35
		D1800, D1900	B10; B12,5; B15; B20; B25; B30; B35; B40
		D2000	B20; B25; B30; B35; B40

Table 9 (continued)

Method of classification	Type of concrete		Grade or mark	
According to compressive durability	Cellular concrete corresponding to average volume mass		Distilled	Undistilled
		D500	B1; B1,5;	
		D600	B1; B1,5; B2	B1,5; B2; B2,5
		D700	B1,5; B2; B2,5; B3,5	B1,5; B2; B2,5
		D800	B2,5; B3,5; B5	B2; B2,5; B3,5
		D900	B3,5; B5; B7,5	B3,5; B5
		D1000	B5; B7,5; B10	B5; B7,5
		D1100	B7,5; B10; B12,5; B15	B7,5; B10
		D1200	B10; B12,5; B15	B10; B12,5
	Hollow concrete corresponding to average volume mass	D800, D900, D1000	B2,5; B3,5; B5	
		D1100, D1200, D1300	B7,5	
		D1400	B3,5; B5; B7,5	
Longitudinal tensile durability	Heavy-weight concrete, self-stressed concrete, small-particle concrete, light-weight concrete		$B_t0,8$; $B_t1,2$; $B_t1,6$; B_t2; $B_t2,4$; $B_t2,8$; $B_t3,2$	
Antiseepage mark	Heavy-weight concrete, small-particle concrete, light-weight concrete		W2; W4; W6; W8; W10; W12	
Mark according to average volume mass	Light-weight concrete		D800; D900; D1000; D1100; D1200; D1300; D1400; D1500; D1600; D1700; D1800; D1900; D2000	
	Cellular concrete		D500; D600; D700; D800; D900; D1000; D1100; D1200	
	Hollow concrete		D800; D900; D1000; D1100; D1200; D1300; D1400	
Mark according to self-stressed ability	Self-stressed concrete		$S_p0,6$; $S_p0,8$; S_p1; $S_p1,2$; $S_p1,5$; S_p2; S_p3; S_p4.	

Note 1: In this standard, the terms of "lightweight concrete" and "hollow concrete" are used for symbolling for lightweight concrete with solid structure and lightweight concrete with hollow structure (with hollow percentage exceeding 6 percent), respectively..

Note 2: Group of small particle concrete A, B, C should be clearly shown in the design drawings.

5.1.1.4. Age of the concrete for determining compressive and longitudinal tensile durability designated in the design is to base on the real time from the time of execution of the structure to the time it begins to be loaded, on the method of execution, on the condition of hardening of the concrete. When being lack of these above data, the age of the concrete is taken 28 days.

5.1.1.5. For the reinforced concrete structures, it is not allowed to:

- use heavyweight concrete and small particle concrete with compressive durability below B7.5;

- use lightweight concrete with compressive durability below B3,5 for one -layer structure and B2.5 for two-layer structure.

Should use concrete with the compressive durability satisfying the following conditions:

- For reinforced concrete members made from heavyweight concrete and lightweight concrete, when calculating the Repeat load: should not below B15;

- For bar compressive reinforced concrete members made from heavyweight concrete, small particle concrete and lightweight concrete: should not below B15;

- For bar compressive reinforced concrete members bearing large load (for example: Load bearing column of the crane, columns of the downstairs of multi-story buildings): should not below B25.

5.1.1.6. For self-stressed members made from heavyweight concrete, small particle concrete and lightweight concrete with arrangement of tension reinforcement, durable grades of the concrete depending on types and groups of the tension reinforcement, diameter of the tension reinforcement and anchor equipment, taken not below values given in the table 10.

Table 10. Regulation of using durability of the concrete for prestressed structures

Types and groups of tension reinforcement		Durability of the concrete not below
1. Fibre steel of group:		
B-II (with anchor)		B20
Bp-II (without anchor) with the diameter	≤ 5 mm	B20
	≥ 6 mm	B30
K-7 and K-19		B30
2. Bar steel without anchor, with the diameter		
+ from 10 mm to 18 mm, group	CIV, A-IV	B15
	A-V	B20
	A-VI and AT -VII	B30
+ ≥ 20 mm, group	CIV, A-IV	B20
	A-V	B25
	A-VI and AT -VII	B30

Strength of the concrete at the precompressive time R_{bp} (controlled as to compressive durability) should not below 11 MPa, but when using bar steel of A-VI, AT -VI, AT- VIK and AT- VII groups, high strength fibre steel without anchor and cable steel, it is necessary to be designated not below 15,5 MPa. Besides, R_{bp} should not below 50 percent of the compressive durability of the concrete.

For structures designed for bearing repeat load, when using prestressed fibre reinforcement and prestressed bar reinforcement of CIV, A-IV group with any diameter, as well as A-V group with diameter from 10 mm to 18 mm, values of minimum concrete grade given in the table 10 should be increased to one grade (5 MPa) corresponding to increase of concrete strength when beginning bearing prestress.

When designing specific structures, it is allowed to reduce concrete by one grade in minimum, 5 MPa in comparison with values given in the table 10, simultaneously with the reduction of the strength of the concrete when beginning bearing prestress.

Note 1: *When designing reinforced concrete structures in the precompressive period, design characteristics of the concrete is taken as to the durable grades of the concrete, with value equal to strength of the concrete when beginning bearing prestress (according to linear interpolation).*

***Note** 2: In case of designing structures for covering up one layer with the function of thermal insulation, when relative value of precompressive stress* σ_{bp}/R_{bp} *does not exceed 0.3, tension reinforcement of CIV, A-IV groups with the diameter not exceeding 14 mm, for lightweight concrete with grades from B7.5 to B12.5, since then* R_{bp} *need to be designated should not below 80 percent of the durability of the concrete.*

5.1.1.7. When not having specific experimental basis, small particle concrete is not allowed to use for repeat-load bearing reinforced concrete structures as well as for prestressed reinforced concrete structures with span exceeding 12m, using B-II, Bp-II, K-7, K-19 groups.

When using small particle concrete structures, for the purpose of corrosion proof and ensuring the adhesiveness of the concrete with tension reinforcement in the slot and on the concrete surface of the structure, designated compressive durability of the concrete should not below B12.5; but when using for pumping into the tube, using concrete with grade not below B25.

5.1.1.8. In order to insert joints of assembled reinforced concrete members, nominated concrete grade depends on working condition of the member, but taken not below B7.5 for joint without reinforcement and not below B15 for joint with reinforcement.

5.1.2. Standard and design characteristics of the concrete

5.1.2.1. All types of standard strength of the concrete included strength when axially compressing prism standard (prism strength) R_{bn} and axial tensile strength R_{btn}.

Standard strengths of the concrete when calculating according to the first limit state R_b, R_{bt} and the second limit state $R_{b,ser}$, $R_{bt,ser}$ shall be defined by taking standard strength splitting to confidence factor of the corresponding concrete when compressing γ_{bc} and when being tensile γ_{bt}. Values of the γ_{bc} and γ_{bt} factors of some main concrete are given in the table 11.

Table 11. Confidence factor of some types of concrete when compressing γ_{bc} and when being tensile γ_{bt}

Type of concrete	**Values γ_{bc} and γ_{bt} when calculating structure according to limit state**			
	the first group			**the second group** γ_{bc}, γ_{bt}
	γ_{bc}	γ_{bt} **corresponding to durability level of the concrete**		
		Compressive resistant	**Tensile resistant**	
Heavyweight concrete, small particle concrete, self-stressed concrete, lightweight concrete and hollow concrete	1,3	1,5	1,3	1,0
Cellular concrete	1,5	2,3	–	1,0

5.1.2.2. Standard strength of the concrete when axial vertically compressing R_{bn} (standard compressive strength of the concrete) depends on compressive durability of the concrete given in the table 12 (rounded).

Standard strength of the concrete when being axial vertically tensile R_{bnt} (standard compressive strength of the concrete) in case of tensile strength of the concrete not inspected in the process of production shall be determined depending on the compressive durability of the concrete given in the table 12.

Standard strength of the concrete when being axial vertically tensile R_{bn} (standard compressive strength of the concrete) in case of tensile strength of the concrete inspected in the process of production shall be taken as tensile strength with assured probability.

5.1.2.3. Design strengths of the concrete R_b, R_{bt}, $R_{b,ser}$, $R_{bt,ser}$ (rounded) depends on compressive durability and axial tensile strength given in the table 13 and table 14 when calculating according to the first limit states and table 12 when calculating according to the second ones.

Design strengths of the concrete when calculating according to the first limit states R_b, R_{bt} are reduced (increased) by multiplying with working condition factors of the concrete γ_{bi}. These factors concern the specific characteristics of the concrete, long-term of the action, repeated of the load, working condition and period of the structure, method of production, dimension of the section ..etc. Value of the working condition factor γ_{bi} is given in the table 15.

Table 12. Standard strengths of the concrete R_{bn}, R_{btn} and design strength of the concrete when calculating according to the second limit $R_{b,ser}$, $R_{bt,ser}$, MPa

States	Types		Compressive durability of concrete																		
			B1	B1,5	B2	B2,5	B3,5	B5	B7,5	B10	B12,5	B15	B20	B25	B30	B35	B40	B45	B50	B55	B60
							M50	M75	M100	M150	M150	M200	M250	M350	M400	M450	M500	M600	M700	M700	M800
Longitudinal compressive (prism strength) R_{bn} , $R_{b,ser}$	Heavyweight concrete, small particle concrete		-	-	-	-	2,7	3,6	5,5	7,5	9,5	11,0	15,0	18,5	22,0	25,5	29,0	32,0	36,0	39,5	43,0
	Light-weight concrete		-	-	-	1,9	2,7	3,5	5,5	7,5	9,5	11,0	15,0	18,5	22,0	25,5	29,0	-	-	-	-
	Cellular concrete		0,95	1,4	1,9	2,4	3,3	4,6	6,9	9,0	10,5	11,5	-	-	-	-	-	-	-	-	-
Longitudinal tensile R_{btn} , $R_{bt,ser}$	Heavyweight concrete		-	-	-	-	0,39	0,55	0,70	0,85	1,00	1,15	1,40	1,60	1,80	1,95	2,10	2,20	2,30	2,40	2,50
	Small particle concrete	group A	-	-	-	-	0,39	0,55	0,70	0,85	1,00	1,15	1,40	1,60	1,80	1,95	2,10	-	-	-	-
		group B	-	-	-	-	0,26	0,40	0,60	0,70	0,85	0,95	1,15	1,35	1,50	-	-	-	-	-	-
		group C	-	-	-	-	-	-	-	-	-	1,15	1,40	1,60	1,80	1,95	2,10	2,20	2,30	2,40	2,50
	Light-weight concrete	Solid reinforcement	-	-	-	0,29	0,39	0,55	0,70	0,85	1,00	1,15	1,40	1,60	1,80	1,95	2,10	-	-	-	-
		Hollow reinforcement	-	-	-	0,29	0,39	0,55	0,70	0,85	1,00	1,10	1,20	1,35	1,50	1,65	1,80	-	-	-	-
	Cellular concrete		0,14	0,21	0,26	0,31	0,41	0,55	0,63	0,89	1,00	1,05	-	-	-	-	-	-	-	-	-

Note 1: Small particle concrete group, see 5.1.1.3

Note 2: M symbol is used to show the concrete mark regulated previously. Correlation between values of durable grades of the concrete and concrete mark is given in the table A.1 and A.2, Annex A in this standard.

Note 3: Values of the strength of the cellular concrete given in the table corresponding to cellular concrete with the humidity of 10 percent.

Note 4: For Keramzit- Perlit concrete with sand Perlit reinforcement, the values R_{btn} and $R_{bt,ser}$ shall be taken as values of lightweight concrete with soft sand reinforcement multiplying with 0,85.

Note 5: For hollow concrete, R_{bn} and $R_{bt,ser}$ values are taken as to lightweight concrete; R_{btn} and $R_{bt,ser}$ values are multiplied with 0,7.

Note 6: For self-stressed concrete, R_{bn} and $R_{bt,ser}$ values are taken as to heavyweight concrete; R_{btn} and $R_{bt,ser}$ values are multiplied with 1,2.

Table 13. Design strengths of the concrete R_b, R_{bt} when calculating according to the first state, MPa

States	Types		Compressive durability of concrete																		
			B1	B1,5	B2	B2,5	B3,5	B5	B7,5	B10	B12,5	B15	B20	B25	B30	B35	B40	B45	B50	B55	B60
							M50	M75	M100	M150	M150	M200	M250	M350	M400	M450	M500	M600	M700	M700	M800
Longitudinal compressive (prism strength) R_b	Heavyweight concrete, small particle concrete		–	–	–	–	2,1	2,8	4,5	6,0	7,5	8,5	11,5	14,5	17,0	19,5	22,0	25,0	27,5	30,0	33,0
	Light-weight concrete		–	–	–	1,5	2,1	2,8	4,5	6,0	7,5	8,5	11,5	14,5	17,0	19,5	22,0	–	–	–	–
	Cellular concrete		0,63	0,95	1,3	1,6	2,2	3,1	4,6	6,0	7,0	7,7	–	–	–	–	–	–	–	–	–
Longitudinal tensile R_{bt}	Heavyweight concrete		–	–	–	–	0,26	0,37	0,48	0,57	0,66	0,75	0,90	1,05	1,20	1,30	1,40	1,45	1,55	1,60	1,65
	Small particle concrete	group A	–	–	–	–	0,26	0,37	0,48	0,57	0,66	0,75	0,90	1,05	1,20	1,30	1,40	–	–	–	–
		group B	–	–	–	–	0,17	0,27	0,40	0,45	0,51	0,64	0,77	0,90	1,00	–	–	–	–	–	–
		group C	–	–	–	–	–	–	–	–	–	0,75	0,90	1,05	1,20	1,30	1,40	1,45	1,55	1,60	1,65
	Light-weight concrete	solid reinforcement	–	–	–	0,20	0,26	0,37	0,48	0,57	0,66	0,75	0,90	1,05	1,20	1,30	1,40	–	–	–	–
		hollow reinforcement	–	–	–	0,20	0,26	0,37	0,48	0,57	0,66	0,74	0,80	0,90	1,00	1,10	1,20	–	–	–	–
	Cellular concrete		0,06	0,09	0,12	0,14	0,18	0,24	0,28	0,39	0,44	0,46	–	–	–	–	–	–	–	–	–

Note 1: *Small particle concrete group, see 5.1.1.3*

Note *2: M symbol is used to show the concrete mark regulated previously. Correlation between values of durable grades of the concrete and concrete mark is given in the table A.1 and A.2, Annex A in this standard.*

Note *3: Values of the strength of the cellular concrete given in the table corresponding to cellular concrete with the humidity of 10 percent.*

Note *4: For Keramzit- Perlit concrete with sand Perlit reinforcement, the value R_{bt} shall be taken as values of lightweight concrete with soft sand reinforcement multiplying with 0,85.*

Note *5: For hollow concrete, the value R_b is taken as to lightweight concrete; R_{bt} value is multiplied with 0,7.*

Note *6: For self-stressed concrete, R_b value is taken as to heavyweight concrete; R_{bt} value is multiplied with 1,2.*

Table 14. Design tensile strength of the concrete R_{bt} corresponding to the tensile durability of the concrete, MPa

State	Type of concrete	Tensile durability and corresponding marks of the concrete						
		$B_t0.8$	$B_t1.2$	$B_t1.6$	$B_t2.0$	$B_t2.4$	$B_t2.8$	$B_t3.2$
		K10	K15	K20	K25	K30	K35	K40
Longitudinal tensile	Heavyweight concrete, self-stressed concrete, small particle concrete, lightweight concrete	0.62	0.93	1.25	1.55	1.85	2.15	2.45
Note: K symbol is used to show concrete mark according to tensile strength formerly.								

Table 15. Working condition factor of the concrete γ_{bi}

Elements need concerning the working condition factor of the concrete	Working condition factor of the concrete	
	Symbol	Value
1. Repeat load	γ_{b1}	See table 16
2. Long term action of the load: a) When concerning frequent load, long term and short time momentary load except short acting load in which its total action time is short (example load due to crane, conveyor belt; wind load, load appearing in the process of production, transportation and erection...) as well as when concerning special load leading to uneven depression deformation,... + For heavyweight concrete, small particle concrete, lightweight concrete naturally hardened and concrete being thermally cured in the environment condition: - Assurring that concrete is continuosly strengthened according to the time (for example water environment, humid soil or air with humidity over 75%) - Not assuring that concrete is continuosly strengthened according to the time (hot and dry) + For cellular concrete, hollow concrete, it is not dependent on the using condition) b) When concerning short-term momentary load (short action) in the considering combination or special load * not given in 21 for all types of concrete.	γ_{b2}	 1.00 0.09 0.85 1.10

3. Pouring concrete according to standing direction, each layer is over 1.5 m in thick for: - Heavyweight concrete, lightweight concrete and small particle concrete - Cellular concrete and hollow concrete	γ_{b3}	 0.85 0.80
4. Effect of two-axial stress state "compressive-tensile" to strength of the concrete	γ_{b4}	See 7.1.3.1
5. Pouring column concrete according to standing direction, maximum dimension of the column section below 30 cm	γ_{b5}	0.85
6. Prestressed period a) When using fibre steel + For lightweight concrete + For other types of concrete b) Using bar steel + For lightweight concrete + For other types of concrete	γ_{b6}	 1.25 1.10 1.35 1.20
7. Concrete structure	γ_{b7}	0.90
8. Concrete structure made from high strength concrete when concerning the factor γ_{b7}	γ_{b8}	$0.3 + \omega \leq 1$ See 6.2.2.3 for value ω
9. Humidity of cellular concrete + 10% and below + Over 25% + Over 10% and below or equal to 25%	γ_{b9}	 1.00 0.85 Linear interpolation
10. Pouring concrete into joints of assembled members when the width of the joint is below 1.5 of dimension of the member and below 10 cm.	γ_{b10}	1.15
* When supplementing working condition factor in case of concerning special load according to instructions of the corresponding standard (example when concerning earthquake load, $\gamma_{b2} = 1$;		

Note:

1. Working condition factor:

+ Taken according to clauses 1, 2, 7, 9: need to be concerned when determining design strength R_b and R_{bt};

+ Taken according to clause 4: need to be concerned when determining design strength $R_{bt,ser}$;

+ Other sections, only concerned when determining R_b.

2. For Repeat load bearing structure, the factor γ_{b2} is concerned when calculating according to durability, γ_{b1} according to fatigue strength and condition of establishing crack.

3. When calculating load bearing structure in the prestressed period, the factor γ_{b2} is not nessary to be concerned.

4. Working condition factors of the concrete concerned when calculating are not interdependent, but its product should not be below 0.45.

Design strengths of the concrete when designing according to the second limit state, $R_{b,ser}$ and $R_{bt,ser}$ should be multiplied with working condition factor γ_{bi} = 1; except for cases given in the sections 7.1.2.9, 7.1.3.1, 7.1.3.2.

For lightweight concretes, it is allowed to use other values of the design strength when approved.

The above values can be used for lightweight concrete when having reliable basis.

Note: For values of intermediary concrete durability given in 5.1.1.3, values given in the tables 12, 13 and 17 should be taken according to linear interpolation.

5.1.2.4. The initial elastic modulus value of the concrete E_b in compression and tensile shall be taken as in the table 17.

In case of having data on type of cement, concrete compositions, production condition... other values of E_b are allowable to take by the relevant authorities.

5.1.2.5. Thermal expansion factor α_{bt} when the temperature changing from -40^{0}C to 50^{0}C, depending on the type of concrete, shall be taken as follows:

- For heavyweight concrete, small particle concrete and lightweight concrete of small solid reinforcement: 1:10^{-5} $^0C^{-1}$;

- For cellular concrete and hollow concrete: 0.7 x 10^{-5} $^0C^{-1}$

- Lightweight concrete of small hollow reinforcement: 0.8 x 10^{-5} $^0C^{-1}$

In case of having data on mineral compositions of the reinforcement, amount of concrete, aqueous level of the concrete, it is allowable to take other values of α_{bt} if having basis and approved by the relevant authorities.

5.1.2.6. The initial lateral expansion factor of the concrete ν (Poisson factor) shall be taken equal to 0,2 for all types of concrete. Slip modulus of the concrete G is taken equal to 0.4 of the corresponding E_b value. The value of E_b is given in the table 17.

Table 16. Working condition factor of the concrete γ_{b1} when the structure bearing repeat load

Type of concrete	Humidity state of the concrete	The value γ_{b1} corresponding to unsymmetrical factor of the cycle ρ_b						
		0 ÷ 0.1	0.2	0.3	0.4	0.5	0.6	0.7
1. Heavyweight concrete	Natural humidity	0.75	0.80	0.85	0.90	0.95	1.00	1.00
	Saturated	0.50	0.60	0.70	0.80	0.90	0.95	1.00
2. Lightweight concrete	Natural humidity	0.60	0.70	0.80	0.85	0.90	0.95	1.00
	Saturated	0.45	0.55	0.65	0.75	0.85	0.95	1.00

Note: In this table: $\rho_b = \frac{\sigma_{b,min}}{\sigma_{b,max}}$, with $\sigma_{b,\,min}$, $\sigma_{b,\,max}$ corresponding to the mimimum stress and maximum stress of the concrete in a changing period of the load shall be defined according to instructions of 6.3.1.

Table 17. The initial elastic modulus of the concrete in compression and tensile, E_b x 10^{-3}, MPa

Types of concrete			Compressive durability levels and corresponsive marks																		
			B1	**B1,5**	**B2**	**B2,5**	**B3,5**	**B5**	**B7,5**	**B10**	**B12,5**	**B15**	**B20**	**B25**	**B30**	**B35**	**B40**	**B45**	**B50**	**B55**	**B60**
							M50	M75	M100	M150	M150	M200	M250	M350	M400	M450	M500	M600	M700	M700	M800
Heavyweight concrete		naturally hardening	-	-	-	-	9,5	13,0	16,0	18,0	21,0	23,0	27,0	30,0	32,5	34,5	36,0	37,5	39,0	39,5	40,0
		thermally curing at the atmospheric pressure	-	-	-	-	8,5	11,5	14,5	16,0	19,0	20,5	24,0	27,0	29,0	31,0	32,5	34,0	35,0	35,5	36,0
		distilled	-	-	-	-	7,0	9,88	12,0	13,5	16,0	17,0	20,0	22,5	24,5	26,0	27,0	28,0	29,0	29,5	30,0
Small particle concrete, group	A	naturally hardening	-	-	-	-	7,0	10,0	13,5	15,5	17,5	19,5	22,0	24,0	26,0	27,5	28,5	-	-	-	-
		thermally curing at the atmospheric pressure	-	-	-	-	6,5	9,0	12,5	14,0	15,5	17,0	20,0	21,5	23,0	24,0	24,5	-	-	-	-
	B	naturally hardening	-	-	-	-	6,5	9,0	12,5	14,0	15,5	17,0	20,0	21,5	23,0	-	-	-	-	-	-
		thermally curing at the atmospheric pressure	-	-	-	-	5,5	8,0	11,5	13,0	14,5	15,5	17,5	19,0	20,5	-	-	-	-	-	-
	C	distilled	-	-	-	-	-	-	-	-	-	16,5	18,0	19,5	21,0	22,0	23,0	23,5	24,0	24,5	25,0
Lightweight concrete and hollow concrete, with mark according to medium volumetric amount		D800	-	-	-	4,0	4,5	5,0	5,5	-	-	-	-	-	-	-	-	-	-	-	-
		D1000	-	-	–	5,0	5,5	6,3	7,2	8,0	8,4	-	-	-	-	-	-	-	-	-	-
		D1200	-	-	–	6,0	6,7	7,6	8,7	9,5	10,0	10,5	-	-	-	-	-	-	-	-	-
		D1400	-	-	-	7,0	7,8	8,8	10,0	11,0	11,7	12,5	13,5	14,5	15,5	-	-	-	-	-	-
		D1600	-	-	-	-	9,0	10,0	11,5	12,5	13,2	14,0	15,5	16,5	17,5	18,0	-	-	-	-	-
		D1800	-	-	-	-	-	11,2	13,0	14,0	14,7	15,5	17,0	18,5	19,5	20,5	21,0	-	-	-	-
		D2000	-	-	-	-	-	-	14,5	16,0	17,0	18,0	19,5	21,0	22,0	23,0	23,5	-	-	-	-

Table 17 (the end)

Types of concrete		Compressive durability levels and corresponsive marks																		
		B1	**B1,5**	**B2**	**B2,5**	**B3,5**	**B5**	**B7,5**	**B10**	**B12,5**	**B15**	**B20**	**B25**	**B30**	**B35**	**B40**	**B45**	**B50**	**B55**	**B60**
						M50	M75	M100	M150	M150	M200	M250	M350	M400	M450	M500	M600	M700	M700	M800
Lightweight concrete and distilled cellular concrete with mark according to medium volumetric amount	D500	1,1	1,4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D600	1,4	1,7	1,8	2,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D700	-	1,9	2,2	2,5	2,9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D800	-	-	-	2,9	3,4	4,0	-	-	-	-	-	-	-	-	-	-	-	-	-
	D900	-	-	-	-	3,8	4,5	5,5	-	-	-	-	-	-	-	-	-	-	-	-
	D1000	-	-	-	-	-	5,0	6,0	7,0	-	-	-	-	-	-	-	-	-	-	-
	D1100	-	-	-	-	-	-	6,8	7,9	8,3	8,6	-	-	-	-	-	-	-	-	-
	D1200	-	-	-	-	-	-	-	8,4	8,8	9,3	-	-	-	-	-	-	-	-	-

Note 1: See 5.1.1.3 for classification of small particle concrete.

Note 2: M symbol is used to show the previous mark of the concrete. Interrelation between values of durability of the concrete and the mark of the concrete given in the table A.1 and A.2, Annex A in this standard.

Note 3: For lightweight concrete, cellular concrete, hollow concrete with medium volumetric amount in the middle spaces, taking E_b according to liner interpolation. For undistilled cellular concrete, taking E_b similar to distilled concrete, after that multiplying with 0.8.

Note 4: For self-stressed concrete, E_b is taken as to heavyweight concrete, after that multiplying with the factor $\alpha = 0.56 + 0.006B$ in which B is the compressive durability of the concrete.

5.2 Reinforcement

5.2.1 Classification of reinforcement and scope of usage

5.2.1.1 Steels for aggregate of the reinforced concrete structure shall be in accordance with specifications of the State current standards. According to TCVN 1651:1985, there are plain round reinforcement CI and isteg reinforcement (striped reinforcement) CII, CIII, CIV. According to TCVN 3101:1979, there are cold-rolled low carbon steel wires. According to TCVN 3100:1979, there are round fibre steels used as precasted concrete reinforcement.

In this standard, steels imported from Russia are also concerned, included the following types:

a) Bar reinforcement:

- Hot-rolled: plain round of A-I group, with isteg of A-II and Ac-II, A-III, A-IV, A-V, A-VI groups;

- Reinforcement by thermal treatment and thermal mechanical treatment: with isteg of AT-IIIC, AT-IV, AT-IVK, AT-VCK, AT-VI, AT-VIK and AT-VII groups.

b) Fibre reinforcement:

- Cold-rolled fibre steel:

+ Normal type: with flange of Bp-I;

+ High strength type: plain round B-II, with flange Bp-II.

- Cable steel:

+ 7-fibre type K-7 and 19-fibre type K-19.

In the reinforcement concrete structure, method of intensifying the strength by rolling the bar steel of A-IIIB group in the industrial lines is permitted to use (with the control of elongation and stress or control of elongation only). Use of new manufactured steels shall be approved by relevant bodies.

Note:

1. For Russia steels, C symbol is used to show the "weldability" (for example AT-IIIC); "K" shows anticorrosion (for example AT-IVK); "T" used in high strength steel symbol (AT- V). In case of steel required weldability and anticorrosion, using the symbol "CK" (AT- VCK). "c" symbol is used for steels with special nominations (Ac-II).

2. Since now, in the regulations of using steel, the order of steel groups show the priority when using. For example, in 5.2.1.3 noted " should use reinforcement of CIII, A-III, AT- IIIC, AT-IVC, Bp-I, CI, A-I, CII, A-II and Ac-II in the fabric and fastened steel frame" meaning that prior to use CIII, after that are AIII, AT- IIIC...

In order to make available members and joints, hot-rolled plate steel or figured steel should be used in accordance with design standard on steel structure TCXDVN 338:2005.

Steels manufactured according to standards of other countries (included produced by joint venture companies) should comply with specifications of corresponding standards and give the main following norms:

- Chemical compositions and method of manufacture meeting the requirements of steels used in building;
- Norms on strength: yield limit, durability limit and variable factors of these limits;
- Modulus of elasticity, limited elongation, flexibility;
- Weldability;
- With low or high temperature resistant structure, it is necessary to know mechanical property changes when increasing and reducing temperature;
- With repeated-load bearing structure, it is necessary to know fatigue limit.

Note: For steel structures not in accordance with TCVN, it is necessary to base on mechanical norms in order to convert into corresponding reinforcement when selecting scope of using them (see Annex B).

5.2.1.2. Selection of reinforcement depending on type of structures, prestressed or unprestressed as well as condition of execution and using house and works should comply with instructions of 5.2.1.3 and 5.2.1.8 and concerning unification of reinforcement used for structures according to group and diameter,...

5.2.1.3. In order to make tension reinforcement (normal reinforcement) for reinforced concrete structure, using the following types of steel:

a) Bar steel of AT- IVC group: used as longitudinal reinforcement;

b) Bar steel of CIII, A-III and AT- IIIC groups: used as longitudinal and lateral reinforcement;

c) Fibre steel of Bp-I group: used as horizontal and longitudinal reinforcement;

d) Bar steel of CI, A-I, CII, A-II and Ac-II groups: used as horizontal as well as longitudinal reinforcement (if other normal steel can not be used);

e) Bar steel of CIV, A-IV (A-IV, AT-VK, AT- VCK): used as longitudinal reinforcement in fabric and

fastened steel frame.

f) Bar steel of CIV, A-IV (A-IV, AT-VK, AT- VCK), A-IV (A-VI, AT-VI, AT-VIK), AT-VII groups: used as compressive longitudinal reinforcement as well as the tension and compressive longitudinal reinforcement in case of arranging both normal reinforcement and tension reinforcement in fabric and fastened steel frame.

In order to make intensile reinforcement, reinforcement of A-IIIB group can be used as tensile longitudinal reinforcement in fabric and fastened steel frame.

Reinforcement of CIII, A-III, AT-IIIC, AT-IVC, Bp-I, CI, A-I, CII, A-II and Ac-II groups should be used in fabric and fastened steel frame.

The reinforcement of A-IIIB, AT-IVK groups (made from steel marks 10MnSi2, 08Mn2Si) and AT- V (made from steel mark 20MnSi) can be used as welded fabric and steel frame in the cross association by point welding (see 8.8.1).

5.2.1.4. In structures using normal reinforcement, bearing gas pressure, liquid and bulk materials, bar reinforcement of CI, A-I, CII, A-II, CIII, A-III and AT-IIIC groups and fibre steel of Bp-I group should be used.

5.2.1.5. In order to make tensile reinforcement for reinforced concrete structure, the following types of steel should be used:

a) Bar steel of A-V (A-V, AT-V, AT-VK, AT-VCK), A-VI (A-VI, AT-VI, AT-VIK) and AT-VII groups;

b) Fibre steel of B-II, Bp-II groups and cable steel K-7 and K-19.

It is allowed to use bar steel of CIV, A-IV (A-IV, AT-IV, AT-IVC, AT-IVK) and A-IIIB groups as tensile reinforcement.

In structures with length not exceeding 12m, it is prior to use bar reinforcement of AT-VII, AT-VI and AT-V.

Note: In order to make tensile reinforcement for prestressed reinforced concrete structures made from lightweight concrete with grade of B7.5 to B12.5, the following bar steels should be used: CIV, A-IV (A-IV, AT-IV, AT-IVC, AT-IVK) and A-IIIB.

5.2.1.6. In order to make tension reinforcement for gas pressure resistant structure, liquid and bulk materials, the following steels should be used:

a) Fibre steel of B-II, Bp-I groups and cable steel K-7 and K-19;

b) Bar steel of A-V (A-V, AT-V, AT-VK, AT-VCK), A-VI (A-VI, AT-VI, AT-VIK) and AT-VII groups;

c) Bar steel of CIV, A-IV (A-IV, AT-IV, AT-IVK, AT-IVC) groups.

In the above structures, steel of A-IIIB group is also allowed to use.

In order to make tension reinforcement in structures working in the strong erosion environment, steel of CIV, A-IV group should be prior to be used as well as steels of AT -VIK, AT -VK, AT -VCK and AT - IVK groups.

5.2.1.7. When selecting type and mark of steel for reinforcement according to design as well as selecting profile rolled steel for readily fixed details, it should concern the condition of thermal use of the structure and load ability according to requirement in the annex A and B.

5.2.1.8. For lifting hook of concrete members and assembled reinforced concrete, hot-rolled reinforcement of Ac-II group, 10MnTi mark and CI, A-I group, CT 3cπ2 mark should be used.

5.2.1.9. In this standard, since now, when not necessary to point out bar steel (hot-rolled, thermal treatment), steel group symbol uses symbol of hot -rolled reinforcement (for example A-V steel group is understood as reinforcement of A-V, AT-VK and AT-VCK groups).

5.2.2. Standard and design characteristics of the reinforcement

5.2.2.1. Standard strength of the reinforcement R_{sn} is the controlled minimum value of the real or conventional yield limit (equal to stress corresponding to residual deformation of 0.2%).

The above mentioned characteristics of the reinforcement are taken in accordance with current standards of the State and technical requirements of the reinforcement for assuring that probability is not below 95%.

Standard strength R_{sn} of some fibre and bar steels is given in the table 18 and table 19; see annex B for other types of steel.

5.2.2.2. Design tensile strength Rs of the reinforcement when calculating according to the first and second limit states is defined according to the following formula:

$$R_s = \frac{R_{sn}}{\gamma_s} \qquad (10)$$

In which γ_s- confident factor of the reinforcement, taken according to table 20. See annex B for other types of steel.

Table 18. Standard tensile strength R_{sn} and design tensile strength of bar steel when calculating according to the second limit states $R_{s,ser}$

Group of bar steel	Value R_{sn} and $R_{s,ser}$, MPa
CI, A-I	235
CII, A-II	295
CIII, A-III	390
CIV, A-IV	590
A-V	788
A-VI	980
AT-VII	1175
A-IIIB	540

Note: Steel group symbol taken according to 5.2.1.1 and 5.2.1.9..

Table 19. Standard tensile strength R_{sn} and design tensile strength of fibre steel when calculating according to the second limit states $R_{s,ser}$

Group of fibre steel	Durability	Diameter, mm	R_{sn} and $R_{s,ser}$, MPa values
Bp-I	-	3; 4; 5	490
B-II	1500	3	1500
	1400	4; 5	1400
	1300	6	1300
	1200	7	1200
	1100	8	1100
Bp-II	1500	3	1500
	1400	4; 5	1400
	1200	6	1200
	1100	7	1100
	1000	8	1000
K-7	1500	6; 9; 12	1500
	1400	15	1400
K-19	1500	14	1500

Note:

1. Durability level of fibre steel is the value of conventional yield limit, by MPa.

2. For fibre of B-II; Bp-II, K-7 and K-19 groups, durability is clearly shown in symbol, for example:

- Symbol of fibre steel of B-II group with diameter of 3 mm: ϕ 3B1500

- Symbol of fibre steel of Bp -II group with diameter of 5 mm: ϕ 5Bp1400

- Symbol of cable steel of K-7 group with diameter of 12 mm: ϕ 12K7-1500

Table 20. Confident factor of the reinforcement γ_s

Group of bar steel			γ_s value when calculating structure according to the limit states: the first	the second
Bar steel	CI, A-I, CII, A-II		1,05	1,00
	CIII, A-III with diameter, mm	6 ÷ 8	1,10	1,00
		10 ÷ 40	1,07	1,00
	CIV, A-IV, A-V		1,15	1,00
	A-VI, AT-VII		1,20	1,00
	A-IIIB	with control of elongation and stress	1,10	1,00
		with control of elongation only	1,20	1,00
Fibre steel	Bp-I		1,20	1,00
	B-II, Bp-II		1,20	1,00
Cable steel	K-7, K-19		1,20	1,00

Note: Steel group symbol is taken according to 5.2.1.1 and 5.2.1.9.

5.2.2.3. Design compressive durability of the reinforcement R_{sc} used in designing structure according to the first limit states when having adhesion between concrete and reinforcement is taken according to table 21 and 22.

When calculating in the precompression period of the structure, the value R_{sc} is taken not exceeding 330 MPa; for steel group of A-IIIB, taken equal to 170 MPa.

When without adhesion between concrete and reinforcement, $R_{sc} = 0$.

5.2.2.4. Design strength of the reinforcement when calculating according to the first limit states is reduced (or increased) by multiplying with working condition factor of the reinforcement γ_{si}. This factor concerns the danger due to fatigue destruction, unequal stress distribution in section, anchor condition, strength of concrete around the reinforcement... or when the reinforcement is under the condition that stress exceeds conventional yield limit, property change of the steel due to production condition...

Design strength of the reinforcement when calculating according to the second limit states $R_{s,ser}$ is put into calculation with working condition factor of $\gamma_{si} = 1.0$

Design strength of lateral reinforcement (stirrup and inclined reinforcement) R_{sw} is reduced in comparison with R_s by multiplying with working condition factors γ_{s1}, γ_{s2}. These factors are taken as follows:

a) Not depending on type and mark of steel: $\gamma_{s1} = 0.8$ (γ_{s1} concerning uneven stress distribution in reinforcement);

Table 21. Design strength of the reinforcement when calculating according to the first limit states

Group of bar steel		**Tensile strength, MPa**		**Compressive strength** R_{sc}
		Longitudinal reinforcement R_s	**Lateral reinforcement (stirrup, inclined reinforcement)** R_{sw}	
CI, A-I		225	175	225
CII, A-II		280	225	280
A-III with diameter, mm	6 ÷ 8	355	285*	355
CIII, A-III with diameter, mm	10 ÷ 40	365	290*	365
CIV, A-IV		510	405	450**
A-V		680	545	500**
A-VI		815	650	500**
AT-VII		980	785	500**
A-IIIB	with control of elongation and stress	490	390	200
	with control of elongation only	450	360	200

* In welded steel frame, for stirrup reinforcement made of steel group CIII, A-III with diameter below 1/3 diameter of longitudinal reinforcement, R_{sw} = 255 MPa.

** The above R_{sc} taken for structures made from heavyweight concrete, small particle concrete, lightweight concrete when concerning the calculation of loads taken according to 2a in Table 15; when concerning loads taken according to 2b in Table 15, R_{sc} = 400 MPa. For structures made from cellular concrete and hollow concrete, R_{sc} = 400 Mpa for all cases.

Note 1: In all cases, for any reasons, untensioned reinforcement of CII, A-III group and over is used as lateral reinforcement (stirrup, or inclined reinforcement); design strength value R_{sw} is taken as to steel of CIII, A-III group.

Note 2: See 5.2.1.1 and 5.2.1.9 for steel group symbol.

Table 22. Design strength of fibre reinforcement when calculating according to the first limit states, MPa

Group of fibre steel	Diameter of fibre steel, mm	Design tensile strength		Design Compressive strength R_{sc}
		Longitudinal reinforcement R_s	Lateral reinforcement (stirrup, inclined reinforcement) R_{sw}	
Bp-I	3; 4; 5	410	290*	375**
B-II with durability levels				
1500	3	1250	1000	
1400	4; 5	1170	940	
1300	6	1050	835	
1200	7	1000	785	
1100	8	915	730	
Bp-II durability levels				
1500	3	1250	1000	500**
1400	4; 5	1170	940	
1200	6	1000	785	
1100	7	915	730	
1000	8	850	680	
K-7 durability levels				
1500	6; 9; 12	1250	1000	
1400	15	1160	945	
K-19	14	1250	1000	

* When using fibre steel in fastened steel frame, the value R_{sw} should be taken equal to 325 MPa.

** These above values of R_{sc} shall be taken according to 2a in the table 15 when calculating structures made from load-bearing heavyweight concrete, small particle concrete and lightweight concrete; when calculating load-bearing structure according to 2b in table 15, the value R_{sc} = 400 MPa as well as when calculating structures made from load-bearing cellular concrete and hollow concrete, the value R_{sc} is taken as follows: For fibre steel of Bp-I group, taken equal to 340 MPa; for Bp-II, K-7 and K-19 groups, taken equal to 400 MPa.

b) For bar steel of CIII, A-III group with diameter below 1/3 of diameter of the longitudinal steel and for fibre steel of Bp-I group in the welded steel frame: γ_{s2} = 0.9 (γ_{s2} concerning interweldability being destroyed)

Design tensile strength of lateral reinforcement (stirrup, inclined reinforcement) R_{sw} concerning the above working condition factors γ_{s1}, γ_{s2} in table 21, 22.

Besides, design strengths R_s, R_{sc}, R_{sw} in the corresponding cases should be multiplied with working condition factors of the reinforcement. These factors are given in the table 23 to 26.

Table 23. Working condition factors of the reinforcement γ_{si}

Elements need concerning working condition factor of the reinforcement	Characteristics of the reinforcement	Group of reinforcement	γ_{si} values		
			Symbol	Value	
1. Shear reinforcement	Lateral reinforcement	All types	γ_{s1}	See 5.2.2.4	
2. With welded joint when bearing shear force	Lateral reinforcement	CIII, A-III; Bp-I	γ_{s2}	See 5.2.2.4	
3. Repeat load	Longitudinal and lateral reinforcement	All types	γ_{s3}	See table 24	
4. With welded joint when bearing Repeat load	Longitudinal and lateral reinforcement when having welded connection	CI, A-I; CII, A-II; CIII, A-III; CIV, A-IV; A-V	γ_{s4}	See table 25	
5. Stressed transmission section for reinforcement without anchor and anchor section of untensioned	Tension longitudinal reinforcement	All types	γ_{s5}	l_x/l_p	In which: l_x - space from the beginning of the stressed transmission section to design section;
	Untensioned longitudinal reinforcement			l_x/l_{an}	

Table 23. (the end)

reinforcement					l_p, l_{an} - is length of the stressed transmission section and anchor section of the reinforcement (See 5.2.2.5 and 8.5.2)
6. High strength reinforcement under the condition that stress exceeds the conventional yield limit	Tension longitudinal reinforcement	CIV, A-IV; A-V; A-VI; Aт-VII; B-II; K-7; K-19	γ_{s6}	See 6.2.2.4	
7. Members made from lightweight concrete of B7.5 grade and below	Lateral reinforcement	CI, A-I; Bp-I	γ_{s7}	0.8	
8. Members made from cellular concrete of B7.5 grade and below	Compressive longitudinal reinforcement	All types	γ_{s8}	$\frac{190+40B}{R_{sc}} \leq 1$	
	Lateral reinforcement			$\frac{25B}{R_{sw}} \leq 1$	
9. Reinforcement protective coating in structures made from cellular concrete	Compressive longitudinal reinforcement	All types	γ_{s9}	See table 26	

Note:

1. The factors γ_{s3} and γ_{s4} in item 3 and 4 of this table concerned only in calculating fatigue; for reinforcement with welded joint, these above factors are simultaneously concerned.

2. The factor γ_{s5} in item 5 of this table is used for both design strength R_s and prestress in reinforcement γ_{sp}.

3. In the formula in item 8 of this table, R_{sc} and R_{sw} is calculated by MPa; B value (compressive durability of the concrete, MPa) is taken according to 5.1.1.2.

Table 24. Working condition factor of the reinforcement γ_{s3} when the structure bears repeat load

Group of reinforcement		The value γ_{s3} corresponding to unsymmetrical factor of the cycle ρ_s is								
		-1.0	-0.2	0	0.2	0.4	0.7	0.8	0.9	1.0
CI, A-I		0.41	0.63	0.70	0.77	0.90	1.00	1.00	1.00	1.00
CII, A-II		0.42	0.51	0.55	0.60	0.69	0.93	1.00	1.00	1.00
A-III, diameter, mm	6 ÷ 8	0.33	0.38	0.42	0.47	0.57	0.85	0.95	1.00	1.00
CIII, A-III, diameter, mm	10 ÷ 40	0.31	0.36	0.40	0.45	0.55	0.81	0.91	0.95	1.00
CIV, A-IV		-	-	-	-	0.38	0.72	0.91	0.96	1.00
A-V		-	-	-	-	0.27	0.55	0.69	0.87	1.00
A-VI		-	-	-	-	0.19	0.53	0.67	0.87	1.00
A_T-VII		-	-	-	-	0.15	0.40	0.60	0.80	1.00
Bp-II		-	-	-	-	-	0.67	0.82	0.91	1.00
B-II		-	-	-	-	-	0.77	0.97	1.00	1.00
K-7, diameter, mm	6 ÷ 9	-	-	-	-	-	0.77	0.92	1.00	1.00
	12 ÷ 15	-	-	-	-	-	0.68	0.84	1.00	1.00
K-19 diameter of 14 mm		-	-	-	-	-	0.63	0.77	0.96	1.00
Bp-I		-	-	0.56	0.71	0.85	0.94	1.00	1.00	1.00
$A\text{-}III_B$	With control of elongation and stress	-	-	-	-		0.66	0.84	1.00	1.00
	With control of stress only	-	-	-	-		0.73	0.93	1.00	1.00

Note 1: $\rho_s = \frac{\sigma_{s,min}}{\sigma_{s,max}}$, *in which* $\sigma_{s,min}$, $\sigma_{s,max}$ *- the minimum and maximum stress in the reinforcement in a changing cycle of the load, defined according to 6.3.1.*

Note 2. When calculating bending member made from heavyweight concrete and untensioned reinforcement, for longitudinal reinforcement, defined as follows:

+ If $0 \le \frac{M_{\min}}{M_{\max}} \le 0,20$ $\qquad \rho_s = 0,30;$

+ If $0,20 < \frac{M_{min}}{M_{max}} \le 0,75$ $\qquad \rho_s = 0,15 + 0,8\frac{M_{min}}{M_{max}};$

+ If $\frac{M_{min}}{M_{max}} > 0,75$ $\qquad \rho_s = \frac{M_{min}}{M_{max}},$

In which: M_{min}, M_{max} *- the minimum and maximum bending moment at the design section in a changing cycle of the load.*
Note 3. Corresponding to values ρs *given in the table but without having* γs *value, corresponding steels are not allowed to use.*

Table 25 Working condition factor of the reinforcement γ_{s4}

Group of reinforcement	Welded joint group	When the structure bears repeat load with unsymetrical factor of the cycle ρ_s :						
		0	**0,2**	**0,4**	**0,7**	**0,8**	**0,9**	**1,0**
CI, A-I CII, A-II	1	0,90	0,95	1,00	1,00	1,00	1,00	1,00
	2	0,65	0,70	0,75	0,90	1,00	1,00	1,00
	3	0,25	0,30	0,35	0,50	0,65	0,85	1,00
	4	0,20	0,20	0,25	0,30	0,45	0,65	1,00
CIII, A-III	1	0,90	0,95	1,00	1,00	1,00	1,00	1,00
	2	0,60	0,65	0,65	0,70	0,75	0,85	1,00
	3	0,20	0,25	0,30	0,45	0,60	0,80	1,00
	4	0,15	0,20	0,20	0,30	0,40	0,60	1,00
CIV, A-IV	1	–	–	0,95	0,95	1,00	1,00	1,00
	2	–	–	0,75	0,75	0,80	0,90	1,00
	3	–	–	0,30	0,35	0,55	0,70	1,00
A-V hot rolled	1	–	–	0,95	0,95	1,00	1,00	1,00
	2	–	–	0,75	0,75	0,80	0,90	1,00
	3	–	–	0,35	0,40	0,50	0,70	1,00

Note 1: Groups of welded joint given this table included:

+ Group 1 - butt-welded joint of steel bars (A-II, CII, A-III, CIII, A-IV, CIV, A-V) with similar diameter, mechanically treated before or after welding;

+ Group 2 - Jointing two cruciform intersected steel bars by contact joint; butt-welded joint of two steel bars (A-I, CI, A-II, CII, A-III, CIII) with similar dimension and tacked .

+ Group 3- Welded joint of three cruciform overlapped (three layers) steel bars (A-IIIC) by contact joint; butt-welded joint of two closely jointed steel bars (A-III, CIII); butt-welded joint of two steel bars with gutter; welded joint of two steel bars (A-I, CI, A-II, CII, A-III, CIII, A-IV, CIV, A-V) by two steel bar sections connecting to welding line on the whole of jointed steel section; T-shape welded joint of steel bar and steel plate by contact joint;

+ Group 4:- overlap weld joint of the steel bar (A-I, CI, A-II, CII, A-III, CIII) and steel plate by contact. joint, arc weld; T-shape welded joint of steel bar by arc weld and without minor metal.

Note 2:. In the table, values of γ_{s4} are for reinforcement with diameter to 20 mm.

Note 3: Value of γ_{s4} is reduced by 5% when diameter of the steel bar is 22 mm to 32 mm and reduced by 10% when its diameter exceeds 32 mm.

Table 26. Working condition factor γ_{s9} of the reinforcement

Protective coating		The value γ_{s9} of the reinforcement	
		plain round	with flange
1. Polistirol cement, mineral paint		1.0	1.0
2. Bituminous cement (cold) when the diameter of the reinforcement	≥ 6 mm	0.7	1.0
	< 6 mm	0.7	0.7
3. Silicate bitumen (hot)		0.7	0.7
4. Clay bitumen		0.5	0.7
5. Cement, schist bitumen		0.5	0.5

5.2.2.5. Stress transmission length l_p of tension reinforcement without anchor is defined according to the following formula:

$$l_p = \left(\omega_p \frac{\sigma_{sp}}{R_{bp}} + \lambda_p \right) d \qquad (11)$$

In which: ϖ_p and λ_p - taken according to table 27.

In case of necessary, the value R_{bp} should be multiplied with working condition factors of concrete, except for γ_{b2}.

The value σ_{sp} in the formula (11) is taken equal to:

- The bigger value in two values Rs and σ_{sp} when calculating durability;

- The value σ_{sp} when calculating members according to anticrack ability. In which σ_{sp} has concerned stress loss calculated according to formula from item 1 to 5 of Table 6.

In members made from small particle concrete of group B and lightweight concrete with hollow small reinforcement (except for the concrete of B7.5 to B12.5 grades), the values ϖ_p and λ_p are increased to 1.2 times in comparison with values given in the table 27.

In case of prestress suddenly transmitted to concrete, for flange bar steel , the values ϖ_p and λ_p are increased to 1.25 times. It is not allowed to suddenly transmit compressive prestress when using bar reinforcement with diameter exceeding 18 mm. For flange bar steel of all groups, the value l_p is taken not below 15d.

For fibre steel (except for high strength fibre steel of Bp-II group with anchors in the scope of the slot section) the initial point of prestress transmission section in case of suddenly transmitting compressive prestress into concrete is taken from the end of the member a space of 0.25 l_p.

Table 27. Factors for defining length of stress transmision section l_p of tension reinforcement with anchor

Type and group of steel		Diameter, mm	Factors	
			ω_p	λ_p
1. Flange bar steel (all groups)		Not depending on the diameter	0.25	10
2. Flange high strength fibre steel		5 4 3	1.40 1.40 1.40	40 50 60
3. Cable steel	K-7	15 12 9 6	1.00 1.10 1.25 1.40	25 25 30 40
	K-19	14	1.00	25

Note: For members made from lightweight concrete of grades from B7.5 to b12.5, the values ϖ_p and λ_p *are increased to 1.4 times compared with corresponding values in this table.*

5.2.2.6. Elastic modulus value E_s of reinforcements is given in the table 28.

Table 28. Elastic modulus value of reinforcements

Groups of reinforcement	$E_s.10^{-4}$, MPa
CI, A-I, CII, A-II	21
CIII, A-III	20
CIV, A-IV, A-V, A-VI and AT-VII	19
A-IIIB	18
B-II, Bp-II	20
K-7, K-19	18
Bp-I	17

6. Calculation of reinforcement, reinforced concrete according to the first limit state

6.1. Calculation of the reinforcement according to durability

6.1.1 General principles

6.1.1.1. Calculation of the reinforcement according to durability should be carried out on the section perpendicular to the longitudinal axis of the reinforcement. Depending on working conditions of the reinforcement, the calculation can concern or not concern the operation of tension region.

6.1.1.2. For eccentric tension reinforcement given in 4.1.7a in which limit state is characterized by destruction of compressive concrete, the calculation can not concern the operation of tension concrete. Compressive durability of the concrete is conventional as the compressive stress of the concrete with the value equal to R_b and evenly distributed on the compressive zone of the section-conventional compressive zone (figure 2) and hereinafter called compressive region of the concrete.

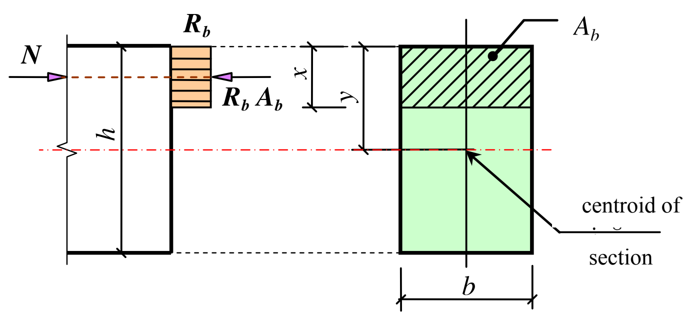


Figure 2. Internal force diagram and stress diagram on the section perpendicular to longitudinal axis of the eccentric compressive concrete member when calculating according to durability not concerning the operation of concrete of tension region.

6.1.1.3. For members given in 4.1.7b as well as members not allowed to be crack according to condition of using structure (water pressure member, cantilever roof, retaining wall,...) when calculating with concerning the operation of the concrete of tension region. Since then limit state is characterized by the destruction of the concrete of tension region (appearing crack). Critical force is defined on the basis of the following suppositions (figure 3):

- Section is still considered flat after being deformed;

- Maximum relative elongation of the extreme tension concrete fibre is taken equal to $2R_{bt}/E_b$;

- Internal stress of the concrete of the compressive zone is defined according to elastic deformation of the concrete (in some cases concerning inelastic deformation);

- Stress of the concrete of the tension region is evenly distributed and equal to R_{bt};

6.1.1.4. When the oblique crack is able to appear (for example the I and T-shape shear bearing member), concrete member should be calculated according to conditions (144) and (145) in which design strength of the concrete when calculated according the second limit states $R_{b,ser}$ and $R_{bt,ser}$ is replaced by values of the corresponding design strength when these values are calculated according to the first limit state R_b and R_{bt};

6.1.1.5. Besides, members should be calculated in order to bear partial action of the load according to 6.2.5.1.

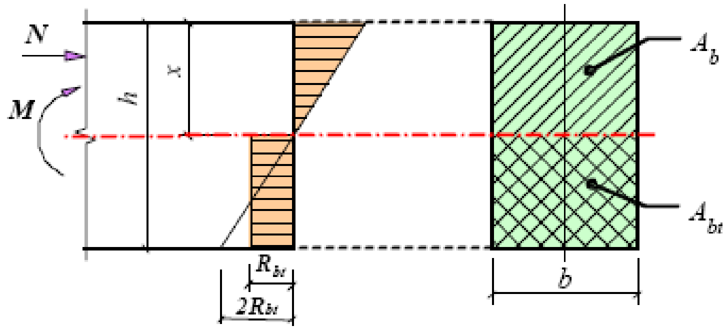


Figure 3. Internal force diagram and stress diagram on the section perpendicular to longitudinal axis of the tension concrete member (eccentrically compressive) when calculating according to durability with concerning the operation of concrete of tension region.

6.1.2. Calculation of eccentric compressive concrete member

6.1.2.1. When calculating the eccentric compressive concrete member, it is necessary to calculate the casual eccentricity e_a of the longitudinal force. The value e_a is defined according to 4.2.12.

6.1.2.2. When the slenderness ratio of the member $l_0/i > 14$, it is necessary to concern the effect of the curvature on the eccentric plane of the longitudinal force and on the plane perpendicular to it and force bearing ability of the member by multiplying the value e_0 with the factor η (see 6.1.2.5). In case of calculating outside the eccentric plane of the longitudinal force, the value e_0 is taken equal to the casual eccentricity e_a.

It is not allowed to use eccentric compressive concrete member (except for the cases given in 4.1.7b) when the eccentricity of longitudinal force setting point has concerned buckling $e_0\eta$ exceeding:

a) According to load combination:

- Basic: 0.90y

- Special: 0.95y

b) According to type and grade of concrete:

- For heavyweight concrete, small particle concrete and lightweight concrete with grade over B7.5: .y-10

- For other type and grade of concrete:...y-20

(In which y is the distance between the centroid of the section and the concrete fibre bearing more compressive, mm).

6.1.2.3. For eccentric compressive concrete members given in 8.11.2, structural reinforcement should be placed.

6.1.2.4. Eccentric compressive concrete member (figure 2) should be calculated as follows:

$$N \le \alpha R_b A_b \qquad (12)$$

In which A_b is the area of compressive concrete region, defined from the central condition of compressive zone with setting point of the combination of external forces.

For member with rectangular section, A_b is defined as follows:

$$A_b = bh\left(1 - \frac{2e_0\eta}{h}\right) \qquad (13)$$

For eccentric compressive concrete members not allowed to appear crack according to condition of using, besides calculations according to the condition (12) , the condition (14) should be checked with the concern of the operation of the tensile region concrete (see 6.1.1, figure 3):

$$N \le \frac{\alpha R_{bt} W_{pl}}{e_0 \eta - r} \qquad (14)$$

For member with rectangular section with the condition (14) having:

$$N \le \frac{1.75\alpha R_{bt} bh}{\frac{6e_0\eta}{h} - \varphi} \qquad (15)$$

The calculation of eccentric compressive concrete member given in 4.1.7b should be defined according to the condition (14) and (15)

In the formulas from 12 to 15:

η - factor, defined according to the formula (19);

α - factor, defined as follows:

- For heavyweight concrete, small particle concrete, lightweight concrete, hollow concrete: 00

- For distilled cellular concrete 0.85

- For undistilled cellular concrete:..0.75

W_{pl}- Unbending moment of the section for the extreme tensile fibre with concern of inelastic deformation of the tensile concrete, defined according to the formula (16) with supposition of without longitudinal force:

$$W_{pl} = \frac{2 I_{b0}}{h - x} + S_{b0} \quad (16)$$

r- the distance from the centre of the section to the core of the section with the extreme compressive zone, defined according to the following formula:

$$r = \varphi \frac{W}{A} \quad (17)$$

φ - see 7.1.2.4;

The position of neutral axis is defined as follows:

$$S'_{b0} = \frac{(h - x) A_{bt}}{2} \quad (18)$$

6.1.2.5. The value of η with the affect of the flexure to eccentricity e_0 of the longitudinal force, defined according to the following formula:

$$\eta = \frac{1}{1 - \frac{N}{N_{cr}}} \quad (19)$$

Where: N_{cr} - conventional critical force, defined as follows:

$$N_{cr} = \frac{6.4 E_b I}{\varphi_l \, l_0^2} \left(\frac{0.11}{0.1 + \delta_e} + 0.1 \right) \quad (20)$$

In which:

- φ_l - the factor concerning the effect of long term action of the load to the flexure of the member at the limit state defined as follows:

$$\varphi_l = 1 + \beta \frac{M_l}{M} \quad (21)$$

But not exceeding 1+ β;

In which:

β- the factor depending on the type of the concrete, taken according to table 29;

M- the moment for the least compressive and tensile border of the section due to effect of the permanent load, long term and short term live load;

M_l - similar to M, but due to permanent load and long term live load;

l_0- defined according to table 30;

δ_e- factor, taken equal to e_0/h, but not below $\delta_{e,\min}$:

$$\delta_{e,\min} = 0.5 - 0.01\frac{l_0}{h} - 0.01R_b \qquad (22)$$

In which: R_b - calculated by MPa.

If bending moment (or eccentricity) due to the total of load and permanent load and long term live load has different mark, the value φ_1 shall be taken as follows:

+ When the absolute value of the eccentricity due to the total of the load $|e_0| > 0.1h$: $\varphi_l = 1$;

+ When $|e_0| \le 0.1h$: $\varphi_l = \varphi_{l1} + 10(1 - \varphi_{l1})\dfrac{e_0}{h}$

In which:

φ_{11} - defined according to the formula (21) with M taken equal to longitudinal force N (due to permanent load, long term and short time live load) multiplying with the distance from the centre of the section to the least tension and compressive edge due to permanent load and long term live load.

Table 29. The factor β in the formula (21):

Type of concrete	**Value β**
1. Heavyweight concrete	1,0
2. Small particle concrete of the group:	
A	1,3
B	1,5
C	1,0
3. Lightweight concrete with:	
+ solid and artificial reinforcement	1,0
+ soft artificial reinforcement	1,5
+ natural reinforcement	2,5
4. Hollow concrete	2,0
5. Cellular concrete:	
+ distilled	1,3
+ undistilled	1,5
*NOTE: Classification of small particle concrete according to group regulated in **5.1.1.3** .*	

Table 30. Design length l_0 of the eccentric compressive concrete member

Bonded characteristics between wall and column	The value l_0
1. With upper and lower bearing	
a) bearing at two ends	H
b) When soaking one end and other end can be transferred for the house:	
- multi-span	1.25H
- single span	1.50H
2. Independently sited	2.00H
Note: H – Height of the column (or wall) between floors excluding the thickness of the floor slab or the height of the independent sited structures	

6.1.2.6. Calculation of partial compressive concrete member shall be made in accordance with 6.2.5.1 and 6.2.5.2.

6.1.3. Member in bending

6.1.3.1. Bending concrete member (figure 3) shall be calculated as follows:

$$M \le \alpha R_{bt} W_{pl} \qquad (23)$$

In which:

α- factor, taken according to 6.1.2.4;

W_{pl} - defined according to the formula (16), for the member with rectangular section W_{pl} is defined as follows:

$$W_{pl} = \frac{bh^2}{3.5} \qquad (24)$$

6.2. Calculation of the reinforced concrete member according to durability

6.2.1 General principles

6.2.1.1. Reinforced concrete member shall be calculated on the section perpendicular to longitudinal axis of the member and on the section oblique to the longitudinal axis of the member according to the most dangerous direction. When having torsion moment, it is necessary to check space section durability limited by torsion cracks at the tensile zone according to the most dangerous direction possibly occurring. Besides, members bearing partial actions of the load (partial compressive, pierced compression, jack).

6.2.1.2. When having unadhesive tension reinforcement, calculation of structure according to the durability shall be made in accordance with specific instructions.

6.2.2. Calculation according to the section perpendicular to the longitudinal axis of the member.

6.2.2.1. Critical interior force on the perpendicular section shall be defined according to the following suppositions:

- Ignore the tensile bearing capability of the concrete;

- Compressive bearing capability of the concrete is stress, taken equal to Rb, evenly distributed on the compressive zone;

- Reinforcement deformation (stress) is defined depending on the height of the compressive zone of the concrete and concerned the deformation (stress) due to prestress (see 6.2.2.19);

- Tension stress in reinforcement is taken not exceeding the design tensile strength R_s;

- Compressive stress in reinforcement is taken not exceeding the design compressive durability R_{sc}.

6.2.2.2. When the action external force in the plane goes through symmetrical axis of the section and the reinforcement sited according to the edge perpendicular to this plane, calculation of section perpendicular to the longitudinal force of the member can be carried out depending on the interrelation between the relative height values of the compressive zone of the concrete $\xi = x/h_0$, defined by the corresponding balance conditions and relative height value of the compressive zone of the concrete ξ_R (see 6.2.2.3) at the time that when the limit state of the member occurs at the same time when the stress in the tensile reinforcement reaches the design strength R_s with the concern of the corresponding working condition factors except for the factor γ_{s6} (see 6.2.2.4).

6.2.2.3. The value ξ_R is defined according to the following formula:

$$\xi_R = \frac{\omega}{1 + \frac{\sigma_{sR}}{\sigma_{sc,u}}\left(1 - \frac{\omega}{1.1}\right)} \qquad (25)$$

In which:

ω- characteristics of the compressive zone of the concrete, defined as follows:

$$\omega = \alpha - 0{,}008\, R_b \qquad (26)$$

In which:

α- the factor taken as follows:

- For heavyweight concrete: 0.85

- For small particle concrete (see 5.1.1.3) of group A: 0.80

- For small particle concrete of group B, C:... 0.75

- For lightweight concrete, cellular concrete and hollow concrete:............0.80

For distilled concretes (heavyweight concrete, lightweight concrete, hollow concrete, the factor α is reduced to 0.05;

R_b- by MPa;

σ_{sR} - stress in the reinforcement (MPa), for the reinforcement:

- With real yield limit: CI, A-I, CII, A-II, CIII, A-III, A-IIIB, Bp-I:

$\sigma_{sR} = R_s - \sigma_{sp}$;

- With conventional yield limit: CIV, A-IV, A-V, A-VI and AT-VII:

$$+\sigma_{sR} = R_s + 400 - \sigma_{sp} - \Delta\sigma_{sp};$$

- Cable and fibre high strength: BII, Bp-II, K-7, K-19;

$\sigma_{sR} = R_s + 400 - \sigma_{sp}$, ; (in which $\Delta\sigma_{sp} = 0$);

In which:

R_s - design tensile strength with the concern of the corresponding working condition factors γ_{si}, except for γ_{s6} (see 6.2.2.4);

σ_{sp}- is taken with $\gamma_{sp} < 1$;

$\Delta\sigma_{sp}$ - see 6.2.2.19;

$\sigma_{sc,u}$- limiting stress of the reinforcement at the compression zone, taken as follows:

a) For member made from heavyweight concrete, small particle concrete, lightweight concrete depending on the elements give in the table 15:

+ For acting load given in 2a:..500 MPa

+ For acting load given in 2b:..400 MPa

b) For member made from hollow concrete and cellular concrete, in all cases the load is taken equal to 400 MPa. When calculating structure in the precompression period, the value $\sigma_{sc,u}$ = 330 MPa

The value ξ_R defined according to the formula (25) for the members made from cellular concrete should be taken not exceeding 0.6.

6.2.2.4. When calculating according to durability grade, reinforced concrete member uses high strength reinforcement (with conventional yield limit) of CIV, A-IV, A-V, A-VI, AT-VII, B-II, K-7 and K-19 groups, when complying the condition that $\xi < \xi_R$, the tensile strength of the reinforcement R_s should be multiplied with the factor γ_{s6} (see 6 of the table 23) defined according to the following formula:

$$\gamma_{s6} = \eta - (\eta - 1)\left(2\frac{\xi}{\xi_R} - 1\right) \leq \eta \qquad (27)$$

In which:

η - the factor, for the reinforcement of the group:

+ CIV, A-IV:.................................1.20

+ A-V, B-II, Bp-II, K-7, K-19: 1.15

+ A-VI, AT -VII:............................1.10

For the case of centric tension as well as eccentric tension due to longitudinal force sited at the middle of the force combinations in the reinforcement, the value γ_{s6} is taken equal to η.

When the welded joint sited at the member region with the bending moment exceeding 0.9 Mmax (Mmax is the maximum design moment), the value of γ_{s6} for the reinforcement of CIV, A-IV, A-V groups taken not exceeding 1.1; of A-VI and AT-VII groups taken not exceeding 1.05.

The factor γ_{s6} is not concerned for the members:

- calculated repeat load;

- arranged reinforcement from closely placed high strength steel fibres (without hole);

- used in erosion environment

6.2.2.5. For prestressed reinforcement sited at the compression zone when bearing the action of external and internal force of the prestressed period, the design compression strength R_{sc} (see 6.2.2.6, 6.2.2.7, 6.2.2.11, 6.2.2.18) should be replaced by the stress $\sigma_{sc} = \sigma_{sc,u} - \sigma'_{sp}$ (MPa) but not exceeding R_{sc}, in which σ'_{sp} is defined with the factor $\gamma_{sp} > 1$, $\sigma_{sc,u}$ is taken in accordance with 6.2.2.3.

A. Bending member with rectangular section, T-shape, I-shape and ear-ring section.

6.2.2.6. For rectangular sections of bending member given in 6.2.2.2 (figure 4), when $\xi = \frac{x}{h_0} \leq \xi_R$ should be calculated according to the following condition:

$$M \leq R_b bx\,(h_0 - 0{,}5x) + R_{sc}A'_s\,(h_0 - a') \qquad (28)$$

In which, height of the compression zone *x* is defined according to the following condition:

$$R_s A_s - R_{sc}A'_s = R_b bx \qquad (29)$$

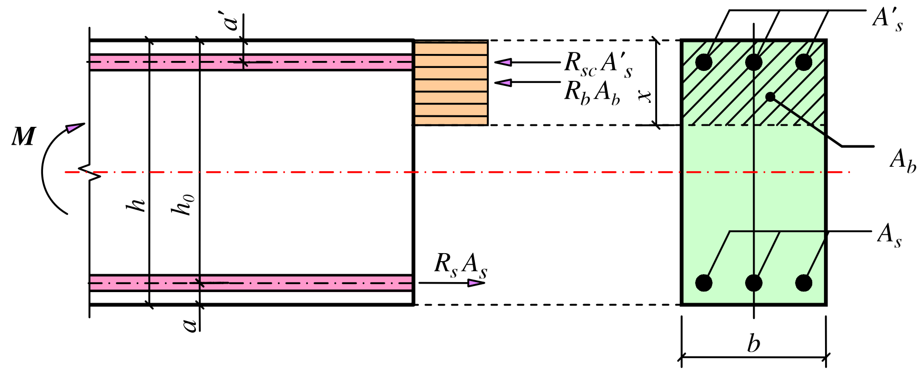


Figure 4: *Internal force diagram and diagram of the stress on the section perpendicular to longitudinal axis of the tension reinforced concrete member when calculating according to durability.*

6.2.2.7. Calculation of flanged section in the compression zone when $\xi = x/h_0 \le \xi_R$ should be made depending on the position of the compression zone border:

a) If the compression zone border goes through the flange (Figure 5a), meaning that it satisfies the condition:

$$R_sA_s \le R_b\, b'_f\, h'_f + R_{sc}A'_s \qquad (30)$$

the calculation is made similar to rectangular section with the width b' f in accordance with 6.2.2.6.

b) If the compression zone border goes through the web (figure 5b), meaning that it does not satisfy the condition (30), the calculation is made according to the following condition:

$$M \le R_b bx\,(h_0 - 0{,}5x) + R_b\,(b'_f - b)\,h'_f\,(h_0 - 0{,}5h'_f) + R_{sc}A'_s\,(h_0 - a') \qquad (31)$$

In which, the height of the compression zone *x* is defined according to the following condition:

$$R_sA_s - R_{sc}A'_s = R_b bx + R_b\,(b'_f - b)\,h'_f \qquad (32)$$

The value b'_f used for calculation is taken from the condition: width of each edge of wing, from the edge of web should not exceed 1/6 span of the member and b'_f should not exceed:

- When having cross member or when $h'_f \ge 0{,}1\,h$:..............................1/2 of the clearance distance among longitudinal members;

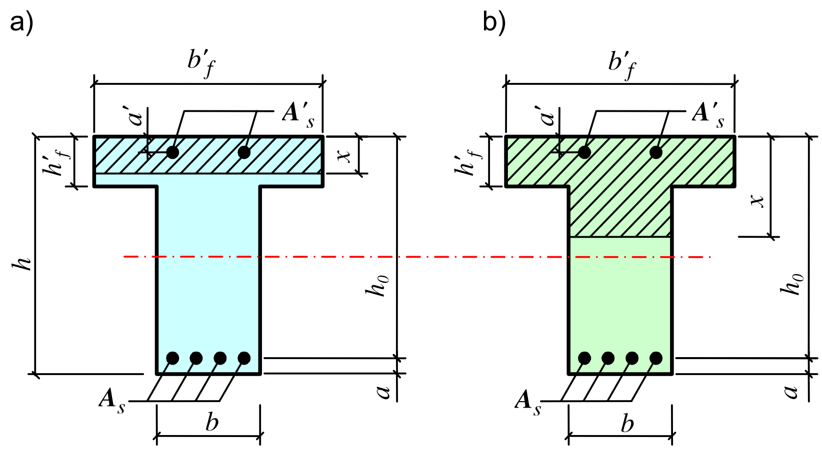
- When there are no horizontal ribs or the distance among them is more than the one among longitudinal ribs, $h'_f < 0{,}1\,h$:……………..$6h'_f$.

- When the flange is in the form of cantilever:

+ In case $h'_f \ge 0.1\,h$: ....$6\,h'_f$

+ In case $0.05\,h \le h'_f < 0.1\,h$:............ $3\,h'_f$

+ In case $h'_f < 0.05\,h$: .... flange is not included in the calculations.



a a- at the flange; b – at the web

Figure 5: *Margin position of the compressed area on the section of the tensioned reinforcement concrete member*

6.2.2.8. When calculating according to the strength of the tensioned member, it is necessary to meet the condition $x \le \xi_R h_0$. In case the area of tensioned reinforcement is in accordance with constructive requirements or from the calculation according to the second limit state which is taken greater in comparison with requirements of reinforcement for it to comply the condition of $x \le \xi_R h_0$, then it is necessary to calculate according to the formula used for the general case (see the clause **6.2.2.19**).

If the calculating results from the formula (29) or (32) show that $x > \xi_R h_0$, it is allowed to calculate according to conditions of (28) and (31), then the height of the corresponding compressed area is determined according to the formulas:

$$\sigma_s A_s - R_{sc} A_s^{'} = R_b b x \qquad (33)$$

$$\sigma_s A_s - R_{sc} A_s^{'} = R_b b x + R_b \left(b_f^{'} - b\right) h_f^{'} \qquad (34)$$

In which:

$$\sigma_s = \frac{0{,}2 + \xi_R}{0{,}2 + \xi + 0{,}35 \dfrac{\sigma_{sp}}{R_s}\left(1 - \dfrac{\xi}{\xi_R}\right)} R_s \qquad (35)$$

Where

$\xi = x/h_0$ (x is determined with value R_s taking into account the work condition corresponding to the reinforcement);

σ_{sp} – is determined with the coefficient $\gamma_{sp} > 1.0$.

For the member made from the concrete of level B30 and lower with the non-tensioned reinforcement of type CI, A-I, CII, A-II, CIII, A-III and Bp-I, when $x > \xi_R h_0$, it is allowed to calculate according to condition (28) and (31), in which replacing the value $x = \xi_R h_0$.

6.2.2.9. For the bending member with the circular section having the ratio between the internal and external radius $r_1/r_2 > 0{,}5$ and the placement of reinforcement is distributed evenly according to the circle (the number of bars aren't less than 6), calculation should be done as the one of the eccentrically compressed member in the clause **6.2.2.12**. Then, in the formula (41), (42), take N = 0 in the formula (40), replacing Ne_0 with the bend moment value M.

B. Eccentrically compressed member with the rectangular and circular sections

6.2.2.10. When calculating eccentrically compressed member, the initial random eccentricity according to clause 4.2.12, as well as the effect of the curvature on the force resistance of member according to the clause 6.2.2.15.

6.2.2.11. The calculation of eccentrically compressed member with rectangular section as mentioned in clause 6.2.2.2 should be done :

a) when $\xi = x/h_0 \le \xi_R$ (Figure 6) according to the condition:

$$Ne \le R_b bx\left(h_0 - 0{,}5x\right) + R_{sc} A_s^{'}\left(h_0 - a'\right) \qquad (36)$$

In which, the height of the compressed area is determined according to the formula:

$$N + R_s A_s - R_{sc} A_s^{'} = R_b bx \qquad (37)$$

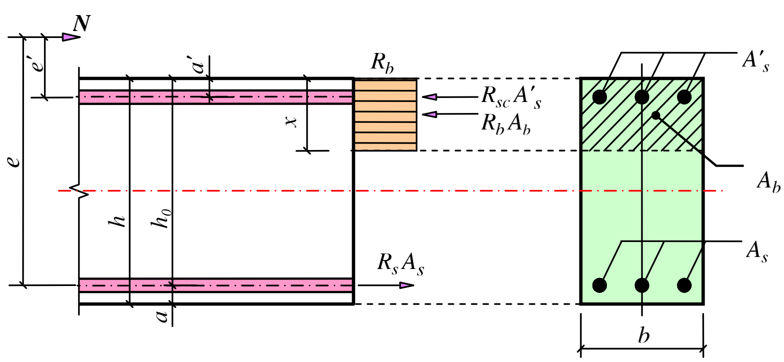


Figure 6: *Circuit of internal force and the diagram of stress on the section in perpendicular to the longitudinal bar of eccentrically compressed reinforcement member as calculating according to the strength*

b) when $\xi = x/h_0 > \xi_R$ – also according to the condition (36) but the height of the compressed area is determined as follow::

- For the member made from the concrete of smaller level or of being equal to B30, reinforcement of type CI, A-I, CII, A-II, CIII, A-III, x is determined according to the formula:

$$N + \sigma_s A_s - R_{sc} A_s^{'} = R_b bx \qquad (38)$$

Where:

$$\sigma_s = \left(2\frac{1 - x/h_0}{1 - \xi_R} - 1\right) R_s \qquad (39)$$

- For the member made from the concrete of level higher than B30 as well as for the member using the reinforcement of type higher than A-III (without or with prestress) – x is determined according to the formulas (66), (67) or (68).

6.2.2.12. For the eccentrically compressed reinforcement member with the circular section with ratio between the internal and external radius $r_1/r_1 \geq 0{,}5$, the reinforcements are distributed evenly according to the circle (the number of longitudinal reinforcement bars is not less than 6), the calculation should be done according to the condition:

$$Ne_0 \leq \left(R_b A r_m + R_{sc} A_{s,tot} r_s\right) \frac{\sin \pi\, \xi_{cir}}{\pi} + R_s A_{s,tot} \varphi_s z_s \qquad (40)$$

In which, the relative area of the concrete in the compressed area is determined according to the formula:

$$\xi_{cir} = \frac{N + \left(\sigma_{sp} + \omega_1 R_s\right) A_{s,tot}}{R_b A + \left(R_{sc} + \omega_2 R_s\right) A_{s,tot}} \qquad (41)$$

If the calculations according to the formula (41) show that the value $\xi_{cir} < 0.15$, in the formula (40), value ξ_{cir} is determined according to the formula:

$$\xi_{cir} = \frac{N + \left(\sigma_{sp} + \varphi_s R_s\right) A_{s,tot}}{R_b A + R_{sc} A_{s,tot}} \qquad (42)$$

in which, values φ_s and z_s are determined according to the formulas (43) and (44) with $\xi_{cir} = 0{,}15$.

In the formulas from (40) to (42):

r_m – average value of the internal and external radius of the section ;

r_s – radius of circle passing through the center of reinforcement;

$A_{s,tot}$ – the area of the whole section of longitudinal reinforcement;

φ_s – coefficient, determined according to the formula:

$$\varphi_s = \omega_1 - \omega_2 \xi_{cir} \qquad (43)$$

z_s – distance from the combined force of tension reinforcement to the centre of the section determined according to the formula (44) but not more than r_s :

$$z_s = \left(0,2 + 1,3\xi_{cir}\right) r_s \qquad (44)$$

σ_{sp} – is determined with the coefficient $\gamma_{sp} > 1$;
ϖ_1 – coefficient, determined according to the formula:

$$\omega_1 = \eta_r - \frac{\sigma_{sp}}{R_s} \qquad (45)$$

where:

η_r – coefficient, taken for the reinforcement:

+ With the real yield limit (type CI, A-I, CII, A-II, CIII, A-III): 1.0

+ With nominal yield limit (type CIV, A-IV, A-V, A-VI, AT-VII, B-II, Bp-II, K-7, K-19): 1.1

Note: For the steel that does not comply with Vietnam standards, see Annex B.

. ϖ_2 – coefficient, determined according to the formula:

$$\omega_2 = \omega_1 \delta \qquad (46)$$

in which, the value δ is taken as:

$$\delta = 1,5 + 6R_s 10^{-4} \qquad (47)$$

R_s – expressed in MPa.

If the calculation results according to formula (43) for value $\varphi_s \leq 0$, in the formula (40), replacing $\varphi_s = 0$ and the value ξ_{cir} calculated from formula (41) with $\omega_1 = \omega_2 = 0$.

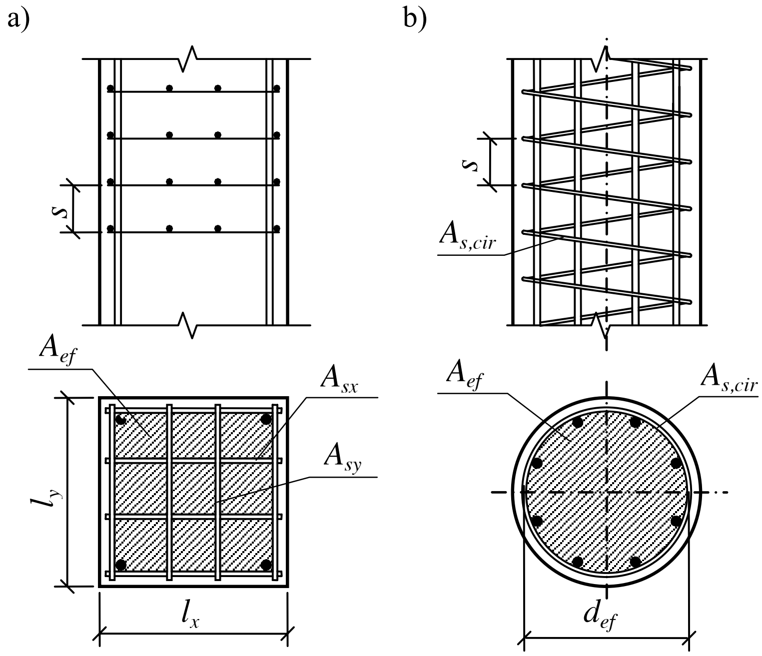
6.2.2.13. Member with solid section made from the heavy concrete, fine concrete which is placed with indirect reinforcement should be calculated according to the instructions in the clauses **6.2.2.11** and **6.2.2.19.** Section that has been put into calculations are concrete section only A_{ef} , limited by the axes of the outermost reinforcement bars of the steel mesh or the axis of the spiral hoop reinforcement (Fig 7). Then R_b in formulas from (36) to (38), (65) and (66) is replaced with the converted cylindral intensity $R_{b,red}$, and when there is the high-strength fibre reinforcement, R_{sc} is replaced with $R_{sc,red}$.

The thinness l_0/i_{ef} of member in which indirect reinforcement is placed shall not be over the value:

+ 55, when the indirect reinforcement is the steel mesh;

+ 35, when the indirect reinforcement is spiral.

In which: i_{ef} – inertia radius of the section that is brought into calculations.



a) of steel mesh type; b) of spiral reinforcement type

Figure 7. Compression member with the placement of indirect reinforcement

Value $R_{b,red}$ is determined according to the following formulas :

a) when the indirect reinforcement is the steel mesh, $R_{b,red}$ is calculated as follow:

$$R_{b,red} = R_b + \varphi \mu_{xy} R_{s,xy} \tag{48}$$

in which, $R_{s,xy}$ is the calculating intensity of the bar inside the steel mesh;

$$\mu_{xy} = \frac{n_x A_{sx} l_x + n_y A_{sy} l_y}{A_{ef} s} \tag{49}$$

where:

n_x, A_{sx}, l_x – respectively the number of bars, section area and the length of bar inside the steel mesh (calculated according to the distance between the axis of the outermost reinforcement bars) in one direction;

n_y, A_{sy}, l_y – similarly, but in another direction;

A_{ef} – concrete area within the steel mesh;

s – distance between steel mesh;

φ – coefficient including the impact of indirect reinforcement, is determined according to the formula:

$$\varphi = \frac{1}{0{,}23 + \psi} \tag{50}$$

With $\psi = \frac{\mu_{xy} R_{s,xy}}{R_b + 10}$ (51)

$R_{s,xy}$, R_b is expressed in MPa.

For the member made from the fine concrete, coefficient *j* is taken not more than 1.0. The section area of the bars inside the steel mesh in one unit of length in this direction or another shall not be different more than 1.5 times.

b) When placing the spiral or hoop indirect reinforcement, $R_{b,red}$ is calculated according to the formula :

$$R_{b,red} = R_b + 2\mu_{cir} R_{s,cir} \left(1 - \frac{7{,}5e_0}{d_{ef}}\right) \quad (52)$$

in which:

e_0 – eccentricity of the longitude force (not including the impact of the curvature);

$R_{s,cir}$ – calculating intensity of the spiral reinforcement;

μ_{cir} – reinforcement content, is taken equal to:

$$\mu_{cir} = \frac{4A_{s,cir}}{d_{ef} s} \quad (53)$$

where:

$A_{s,cir}$ – section area of the spiral reinforcement;

d_{ef} – section diameter inside spiral reinforcement;

s – spiral step.

Value of the reinforcement content determined according to the formulas (49) and (53), for the member made from the fine concrete is taken not more than 0.04.

Converted calculating compression intensity $R_{sc,red}$ of the high-strength longitudinal reinforcement of types CIV, A-IV, A-V, A-VI and AT-VII, for the member made from the heavy concrete with the indirect reinforcement of welded steel mesh is determined according to the formulary (54):

$$R_{sc,red} = R_{sc} \frac{1 + \delta_1 \left[\left(\frac{R_s}{R_{sc}}\right)^2 - 1\right]}{1 + \delta_1 \left(\frac{R_s}{R_{sc}} - 1\right)} \quad (54)$$

but taken not more than R_s .

In the formula (54):

$$\delta_1 = \frac{8{,}5\, E_s\, \psi\, \theta}{R_s \cdot 10^3} \qquad (55)$$

In which: $\theta = 0{,}8 + \eta \frac{A_{s,tot}}{A_{ef}} \left(1 - \frac{R_b}{100}\right)$

where:

η – coefficient, is taken as follow :

+ for the reinforcement of types CIV, A-IV: 10

+ for the reinforcement of types A-V, A-VI, AT-VII: 25

$A_{s,tot}$ – the entire section area of the high-strength vertical reinforcement bars;

A_{ef} – as in the formula (49);

R_b – expressed in MPa.

Value θ is taken not less than 1.0 and not more than:

+ for the reinforcement of types CIV, A-IV: 1.2

+ for the reinforcement of types A-V, A-VI, AT-VII: 1.6.

When determining the limit value of the relative height of the compression are for the section with the indirect reinforcement according to the formula (25), the value *w* is taken according to the formula:

$$\omega = \alpha - 0{,}008\ R_b + \delta_2 \leq 0{,}9 \qquad (56)$$

in which:

α – coefficient, is taken according to clause **6.2.2.3** ;

δ_2 – coefficient, is taken equal to 10 μ , but not more than 0.15;

where, μ is the reinforcement content μ_{xy} or μ_{cir} is determined according to the formula (49) and (53) respectively for the indirect reinforcement of steel mesh or spiral type.

Value $\sigma_{sc,u}$ in the formula (25) for the member with high-strength reinforcement is taken equal to:

$$\sigma_{sc,u} = \left(2 + 8{,}5\psi\theta\right) E_s \cdot 10^{-3} \qquad (57)$$

but not more than:

- 900 MPa for the reinforcement of types CIV, A-IV;

- 1200 MPa for the reinforcement of types A-V, A-VI, AT-VII.

In considering the impact of the curvature to the force bearing capacity of the member with the placement of indirect reinforcement, use the instructions at the clause **6.2.2.15** when determining the inertia moment of the section limited by bars of steel mesh or the part in the scope of spiral hoop. Value N_{cr} calculated from the formula (58) shall be multiplied with the coefficient $\varphi_1 = 0{,}25 + 0{,}05\, l_0/c_{ef} \le 1{,}0$ (where: c_{ef} is equal to the height or the diameter of the concrete section included in the calculations), and when determining $\delta_{e,\min}$, the second term in the right hand side of the formulary (22) is replaced with $0{,}01(l_0/c_{ef})\varphi_2$, in which $\varphi_2 = 0{,}1\,(l_0/c_{ef}) - 1 \le 1{,}0$.

Indirect reinforcement included in the calculations with the condition that when the force bearing capacity of members determined according to instructions of this clause (with A_{ef} and $R_{b,red}$) exceed themselves force bearing capacity determined according to the integer section A and the value of calculating concrete intensity R_b not including the impacts of the indirect reinforcement.

Besides, indirect reinforcement shall meet the constructive requirements according to subclause **8.7.3.**

6.2.2.14. When calculating the eccentrically compressed members with the indirect reinforcement, besides the calculations according to the strength according to the clause **6.2.2.13**, it is necessary to find the way to prevent the cracks for the protecting concrete layer.

The calculations are done according to the instructions of clause **6.2.2.11** and **6.2.2.19** according to the value of using the calculating load (γ_f = 1.0) with the whole concrete section area and the calculating intensity taken equal to $R_{b,ser}$ and $R_{s,ser}$ for the second limit state, calculating intensity of reinforcement taken equal to value $R_{s,ser}$ but not more than 400 MPa.

When determining the limit value of the relative height of the compression area in the formulas (25) and (69), take $\sigma_{sc,u}$ = 400 MPa, and in the formulary (26) the coefficient 0.008 is replaced with 0.006.

In considering the impact of the thinness, comply with the instructions of clause **6.2.2.15**, in which δ_e is determined according to the formula (22) but replacing 0.01 Rb with 0.008 $R_{b,ser}$.

6.2.2.15. When calculating the eccentrically compressed members, take into account the impact of the curvature to the force bearing capacity of members by calculating the structure according to the deformation diagram (see clause **4.2.6**).

Allow to calculate the structure according to the deformation diagram if considering impact of the curvature (when the thinness $l/i > 14$) to the strength, is determined according to the conditions of (36), (40), (65), by multiplying e_0 and coefficient η . Then the conventional limit force in the formula (19) to calculate η is taken as:

$$N_{cr} = \frac{6.4E_b}{l_0^2}\left[\frac{I}{\varphi_l}\left(\frac{0.11}{0.1+\dfrac{\delta_e}{\varphi_p}}+0.1\right)+\alpha I_s\right] \qquad (58)$$

in which:

l_0 – is taken according to clause **6.2.2.16;**

δ_e – coefficient, taken according to clause **6.1.2.5** ;

φ_l – coefficient, is determined according to the formula (21), in which moments *M*, *T* are determined for the axis parallel to the margin line of the compression area and going through the centres of the most tension reinforcement bars or the least ones (when the entire section is compressed). *M* caused by the action of the entire load, *T* caused by the action of frequent and short –term temporary loads. If the above moments (or the eccentricity) have different signs, comply instructions of clause **6.1.2.5** .

φ_p – coefficient in considering the impact of the tensioning reinforcement to the hardness of the member. When the pre-compression force is distributed evenly on the section , φ_p is determined according to the formula:

$$\varphi_p = 1 + 12\frac{\sigma_{bp}}{R_b}\frac{e_0}{h} \qquad (59)$$

where:

σ_{bp} – is determined with the coefficient *g sp* □1,0 ;

R_b – is taken without considering the working condition coefficients of concrete;

value e_0/h is taken not more than 1.5;

$$\alpha = E_s/E_b$$

For the members made from the fine concrete of type B, in the formula (58) value 6.4 is replaced with 5.6.

When calculating the actions of the bent moment out of the plane, the eccentricity of the longitude force e_0 is taken as the random eccentricity (see clause **4.2.12**).

6.2.2.16. Calculating length l_0 of eccentrically compressed reinforcement member should be determined as for member of frame structure with considering its deformation state when placing the load at the most disadvantageous position for the member, with considering the inelastic deformation of materials and the presence of the cracks on the members.

For the members of common structures, allow to take the calculating length l_0 of members as follow:

a) For the pillars of the multi-storey building with the number of spans not less than two, the connection between the beam and pillar is supposed to be hard when the floor structure is:

+ built-up: $l_0 = H$;

+ continuously casted: $l_0 = 0,7H$

where H is the height of storey (distance between the centres of joints);

b) for the pillar of one-storey house in which joint connection with the force bearing floor structure (the system of floor structure is considered to be hard in its plane, with the capacity of horizontal force transmission), as well as pillars of the viaducts: l_0 is taken according to Table 31.

c) For the members of frame and vault: l_0 is taken according to the table 32.

Table 31 - Calculating length l_0 of one-storey house's pillar

Characteristics				Value l_0 when calculating in the plane		
				Horizontal frame or perpendicular to the axis of viaduct	Perpendicular to the horizontal frame or parallel to the axis of viaduct when	
					having	not having
					Braces in the plane of the longitudinal pillar line or the anchoring supports	
House with bridge crane	when including the load caused by the bridge crane	Part of pillar under the crane beam	uncontinuous	$1.5H_1$	$0.8H_1$	$1.2H_1$
			continuous	$1.2H_1$	$0.8H_1$	$0.8H_1$
		Part of pillar above the crane beam	uncontinuous	$2.0H_2$	$1.5H_2$	$2.0H_2$
			continuous	$2.0H_2$	$1.5H_2$	$1.5H_2$
	when not including the load caused by the bridge crane	Part of pillar under the crane beam	one span	$1.5H$	$0.8H_1$	$1.2H$
			many spans	$1.2H$	$0.8H_1$	$1.2H$
		Part of pillar above the crane beam	uncontinuous	$2.5H_2$	$1.5H_2$	$2.0H_2$
			continuous	$2.0H_2$	$1.5H_2$	$1.5H_2$
House without bridge crane	step column	Lower part of column	one span	$1.5H$	$0.8H$	$1.2H$
			many spans	$1.2H$	$0.8H$	$1.2H$
		Upper part of column		$2.5H_2$	$2.0H_2$	$2.5H_2$
	pillar with constant section		one span	$1.5H$	$0.8H$	$1.2H$
			many spans	$1.2H$	$0.8H$	$1.2H$
Viaduct	with crane beam		uncontinuous	$2.0H_1$	$0.8H_1$	$1.5H_1$
			continuous	$1.5H_1$	$0.8H_1$	$1.0H_1$
	with connection between the pillar supporting the tubeline and the span		joint	$2.0H$	$1.0H$	$2.0H$
			hard	$1.5H$	$0.7H$	$1.5H$

Note 1:

H– the height of the whole pillar from the upper side of foundation to the horizontal structure (truss frame or the oblique bar of the truss supporting beam) in the corresponding plane;

H_1– height of the lower part of pillar (from the upper side of foundation to the lower side of crane's beam).

H_2– height of the upper part of pillar (from the upper side of the pillar step to the horizontal structure in the corresponding plane).

Note 2: If there is the connection up to the top of pillar in the house with bridge crane, the calculating height of the upper part of pillar in the plane with the longitudinal pillar line is taken as H_2 .

Table 32: Length calculation l_0 of frame member and arch member

<table>
<tr><td colspan="4">Member type</td><td>Length calculation l_0 of frame member and arch member</td></tr>
<tr><td rowspan="7">1. Members of frame</td><td rowspan="4">a) Top boom member on calculation</td><td rowspan="2">on frame plane</td><td>$e_0 < (1/8)h_1$</td><td>0,9 l</td></tr>
<tr><td>$e_0 \geq (1/8)h_1$</td><td>0,8 l</td></tr>
<tr><td rowspan="2">out side frame plane</td><td>below sky light, when the width of sky light is greater or equal to 12m</td><td>0,8 l</td></tr>
<tr><td>The other case</td><td>0,9 l</td></tr>
<tr><td rowspan="3">b) Inclined bar and tie on calculation</td><td colspan="2">on frame plane</td><td>0,8 l</td></tr>
<tr><td rowspan="2">outside frame plane</td><td>$b_1/b_2 < 1,5$</td><td>0,9 l</td></tr>
<tr><td>$b_1/b_2 \geq 1,5$</td><td>0,8 l</td></tr>
<tr><td colspan="2" rowspan="4">2. Arch</td><td rowspan="3">when calculate on frame plane</td><td>3 hinges</td><td>0,580 L</td></tr>
<tr><td>2 hinges</td><td>0,540 L</td></tr>
<tr><td>no hinge</td><td>0,365 L</td></tr>
<tr><td colspan="2">when calculate outside frame plane (any)</td><td>L</td></tr>
<tr><td colspan="5">Note:
l – length of member calculated on center point of node; top boom member of frame when calculate on frame plane, l is space between their connection node;
L –arch length longitudinal to their geometric axis; when calculate outside arch plane, L is space between their connection points on the direction normal to arch plane;
h_1 – height of frame top boom member section;
b_1, b_2 – width of section corresponding to top boom member and tie (inclined bar) of frame.</td></tr>
</table>

C. Centric tensile member

6.2.2.17 When calculating centric tensile reinforced concrete member section should satisfy the following condition:

$$N \leq R_s A_{s,tot} \qquad (60)$$

Where: $A_{s,tot}$ is section area of total longitudinal reinforcement.

D. Eccentric tensile member in rectangular section

6.2.2.18 Calculate eccentric tensile member section in subclause **6.2.2.2** should be verified according to longitudinal force position N:

a) If longitudinal force N place between resultant forces in reinforcement S and S' (Figure 8a), calculate as follows:

$$Ne \leq R_s A_s^{'} \left(h_0 - a'\right) \quad (61)$$

$$Ne' \leq R_s A_s \left(h_0 - a'\right) \quad (62)$$

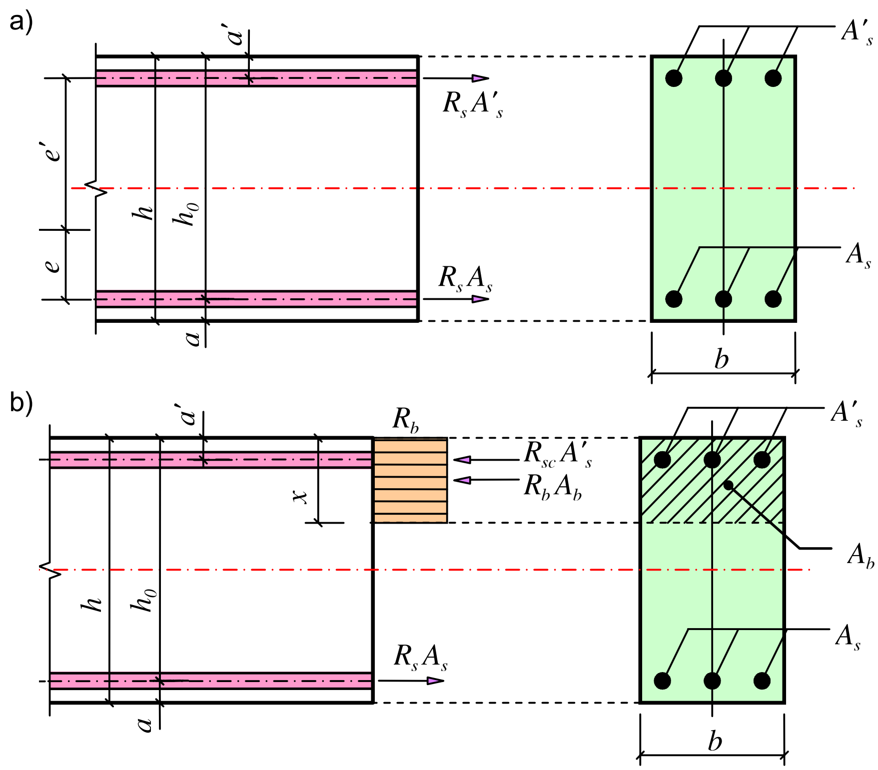
b) If longitudinal force N place outside space between resultant force in reinforcement S and S' (Figure 8b), calculate according to the following condition:

$$Ne \leq R_b bx \left(h_0 - 0{,}5x\right) + R_{sc} A_s^{'} \left(h_0 - a'\right) \quad (63)$$

in which, height of compression zone x is determined by the following equation:

$$R_s A_s - R_{sc} A_s^{'} - N = R_b bx \quad (64)$$

If according to equation (64) calculate value $x > \xi_R h_0$, in equation (63) replace $x = \xi_R h_0$, with ξ_R is determined by subclause **6.2.2.3** .



a – longitudinal force N place between resultant forces of reinforcement S , S';
b – longitudinal force N place outside space between resultant force in reinforcement S , S'

Figure 8 – Internal force outline and stress on section normal to longitudinal axis of eccentric tensile reinforced concrete member chart, when calculate section according to endurance

E. General calculation case

(With section, external force and way to arrange any reinforcement)

6.2.2.19. Section calculation in general case (Figure 9) should be verified by equation:

$$M \le \pm\left(R_b S_b - \sum \sigma_{si} S_{si}\right) \quad (65)$$

in which: "plus" sign before bracket is taken for bent and eccentric compression structure, "minus" sign is taken for tensile structure.

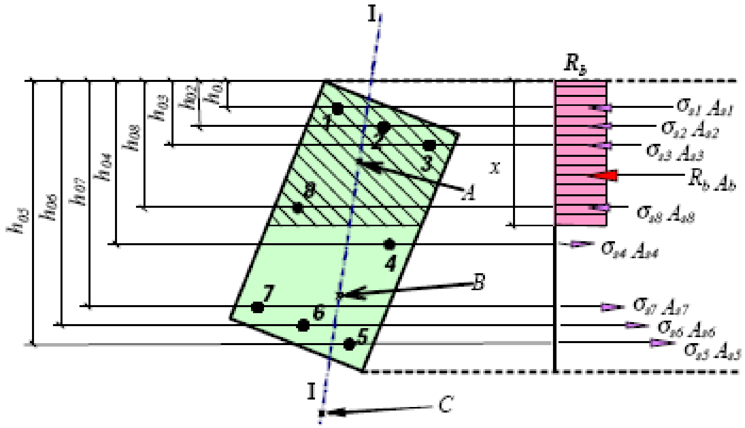


Figure 9 - Internal force outline and stress on section normal to longitudinal axis of eccentric tensile reinforced concrete member chart, when calculate section according to endurance generally

I-I – is plane parallel with effected plane of bent moment, or plane cross longitudinal force point and resultant of compression, tensile internal force; A – resultant force point in compression reinforcement and compression zone concrete; B – resultant force point in tensile reinforcement; C – external force point

In equation (65):

M - in bending member: is projection of moment caused by external force placed on plane normal to line limiting compression zone of section;

– in eccentrically tensile and compressive member: is moment caused by longitudinal force N to axis parallel with line limiting compression zone and cross:

+ center point section of most tensile longitudinal reinforcement bar or less compression when member bearing eccentric compression;

+ point on compression zone, far from line limiting compression zone more than when member bearing eccentric tension;

S_b – static moment of compression concrete zone section area to corresponding axis in the above ones. Then in bent member position of axis is taken in accordance with eccentric compression member case;

S_{si} – static moment of ith longitudinal reinforcement bar area to corresponding axis in the above ones;

σ_{si} – stress in ith longitudinal reinforcement bar is specified by this subclause's instructions.

The height of compression zone x and stress σ_{si} is determined by both equations:

$$R_b A_b - \sum \sigma_{si} A_{si} \pm N = 0 \qquad (66)$$

$$\sigma_{si} = \frac{\sigma_{sc,u}}{1 - \frac{\omega}{1.1}} \left(\frac{\omega}{\xi_i} - 1 \right) + \sigma_{spi} \qquad (67)$$

In equation (66) "minus" sign before value N is for eccentric compression member, "plus" sign is for eccentric tensile member.

Besides, additional condition about parallel of effected plane of external and internal force moment should be obeyed to determine compression zone edge position when bend obliquely. For compression or inclined eccentric tensile should add the condition: placing point of external force effecting longitudinally, of resultant compression force in compression reinforcement and concrete, and resultant force in tensile reinforcement (longitudinal effect external force, resultant compression force in concrete and resultant force of all reinforcement) should be on a line. (figure 9).

If value σsi calculated by equation (67) for reinforcement group CIV, A-IV, A-V, A-VI, AT-VII, B-II, Bp-II, K-7 and K-19 is over βR_{si}, stress σ_{si} shall be determined by equation:

$$\sigma_{si} = \left[\beta + (1 - \beta) \frac{\xi_{eli} - \xi_i}{\xi_{eli} - \xi_{Ri}} \right] R_{si} \qquad (68)$$

In the case stress from equation (68) is over R_{si} excluding coefficient γ_{s6}, in equations (65), (66) value σ_{si} is replaced by R_{si} including corresponding working condition coefficients and coefficient γ_{s6} (see subclause **6.2.2.4**).

Stress σ_{si} with the sign from equations (67) and (68), should obey the following condition when putting into consideration:

- in all cases $R_{si} \geq \sigma_{si} \geq R_{sci}$;

- for pre-stress member $\sigma_{si} > \sigma_{sci}$, where σ_{sci} is stress in reinforcement, is equal to prestress σ'_{spi} that decrease a quantity $\sigma_{sc,u}$ (see subclauses **6.2.2.3** and **6.2.2.13**).

In equations from (66) to (68):

A_{si} – ith reinforcement bar section area;

σ_{spi} – prestress of ith reinforcement bar, calculating to coefficient γ_{sp}, determined according to reinforcement position;

ξ_i – relative height of compression zone of concrete, $\xi_i = x/h_{0i}$, where h_{0i} is space from axis cross center point of i[th] reinforcement bar section and parallel with line limiting compression zone to farthest point of compression zone (Figure 9);

ϖ – compression concrete zone characteristic, is determined by equation (26) or (56);

ξ_{Ri}, ξ_{eli} – relative height of compression zone corresponding to moment that stress in reinforcement reach values R_{si} and βR_{si} respectively; values ξ_{Ri} and ξ_{eli} shall be determined by as follows:

$$\xi_{Ri(eli)} = \frac{\omega}{1 + \frac{\sigma_{s,Ri(eli)}}{\sigma_{sc,u}}\left(1 - \frac{\omega}{1,1}\right)} \qquad (69)$$

where:

when determining ξ_{si} : $\sigma_{s,Ri} = R_{si} + 400 - \sigma_{spi} - \Delta\sigma_{spi}$, $\sigma_{s,Ri}$ calculated by MPa;

when determining ξ_{eli} : $\sigma_{s,eli} = \beta R_{si} - \sigma_{spi}$, $\sigma_{s,eli}$ calculated by MPa;

$\sigma_{sc,u}$ – see subclauses **6.2.2.3** and **6.2.2.13.**

Value $\Delta\sigma_{spi}$ and coefficient β shall be determined as the following:

- When prestress for reinforcements group CIV, A-IV, A-V, A-VI, AT-VII by mechanical method, as well as automatic electro-thermal or automatic mechanical-electro-thermal method, calculate as follows:

$$\Delta\sigma_{spi} = 1500\frac{\sigma_{spi}}{R_{si}} - 1200 \geq 0 \qquad (70)$$

$$\beta = 0.5\frac{\sigma_{spi}}{R_{si}} + 0.4 \geq 0.8 \qquad (71)$$

- When causing prestress for reinforcements group CIV, A-IV, A-V, A-VI, A_T-VII by other methods, as well as prestress for reinforcement group B-II, Bp-II, K-7 and K-19 by any method, taking value $\Delta\sigma_{spi}$ = 0 and coefficient β = 0.8.

In equations (70), (71), σ_{spi} is taken including losses in items from 3 to 5 of table 6 with coefficient $\gamma_{sp} < 1.0$.

Note: indicator *i* is order number of reinforcement bar in consideration.

6.2.3. Calculation on section inclined with longitudinal axis of the member

6.2.3.1 . Reinforcement concrete member calculation according to inclined section should be verified to ensure strength when bearing effects of:

- shear force on inclined lane between inclined cracks (see subclause **6.2.3.2**);

- shear force on inclined crack (see subclauses from **6.2.3.3** to **6.2.3.5**);

- shear force on inclined lane compressed between load position and bearing support (for short cantilever of pile, see subclause **6.2.3.6**);

- bending moment on oblique crack (see subclause **6.2.3.7**).

6.3.2.2. Shear force reinforced concrete member should be calculated to ensure strength on inclined lane between oblique cracks by the following condition:

$$Q \le 0.3\varphi_{w1}\,\varphi_{b1}\,R_b\,bh_0 \qquad (72)$$

Coefficient φ_{w1} , considering effect of stirrup normal to longitudinal axis, shall be determined by equation:

$$\varphi_{w1} = 1 + 5\,\alpha\,\mu_w \qquad (73)$$

but not greater than 1.3,

Where: $\alpha = \frac{E_s}{E_b}$, $\mu_w = \frac{A_{sw}}{bs}$

Coefficient φ_{b1} shall be determined by equation:

$$\varphi_{b1} = 1 - \beta R_b \qquad (74)$$

where:

β – coefficient, taken as the following:

+ for heavy concrete, small particle concrete, cellular concrete: 0,01

+ for light concrete: 0,02

R_b calculated by MPa.

6.2.3.3. To ensure strength according to oblique crack, reinforced concrete member with shear force transversal reinforcement (Figure 10) should be calculated with the most dangerous inclined section by the equation:

$$Q \le Q_b + Q_{sw} + Q_{s,inc} \qquad (75)$$

Shear force Q in equation (75) is determined from external force at one side of considering inclined section.

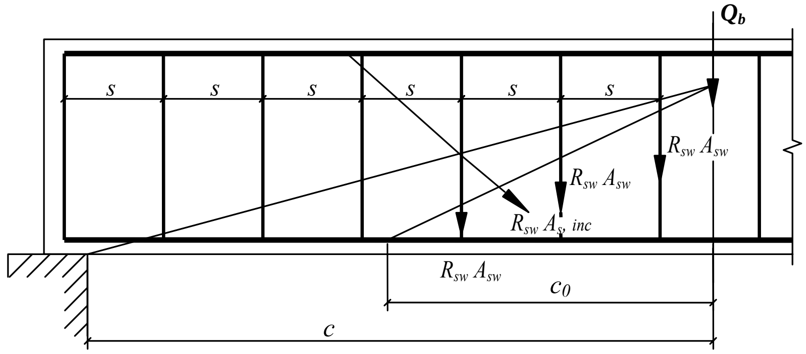


Figure 10 - Internal force on inclined section with longitudinal axis of reinforced concrete member when calculate shear force strength

Shear force Q_b born by own concrete, is determined by equation:

$$Q_b = \frac{\varphi_{b2}\left(1+\varphi_f+\varphi_n\right)R_{bt}\,bh_0^2}{c} \quad (76)$$

where c – projector height of the most dangerous inclined section on member longitudinal axis.

Coefficient φ_{b2} considering effect of concrete type is taken as the following:

- for heavy concrete and cellular concrete: 2.0

- for small particle concrete: 1.7

- for light concrete with mark on average specific mass:

+ ≥D1900 .... 1.90

+ ≤D1800: use hard fine aggregate: 1.75

use porous fine aggregate: 1.50

Coefficient φ_f considering effect of compression flange in T, I section is determined by equation:

$$\varphi_f = 0.75\frac{\left(b'_f - b\right)h'_f}{b\,h_0} \quad (77)$$

But not greater than 0.5.

In equation (77), b'_f is taken not greater than $b+3h'_f$, and transversal reinforcement should be anchored to flange.

Coefficient φ_n, considering effect of longitudinal force, is determined as the following:

- when bearing longitudinal force, determine as the following equation:

$$\varphi_n = 0.1\frac{N}{R_{bt}bh_0} \qquad (78)$$

but not greater than 0.5.

For prestress member, in equation (78) replace N by precompression force P ; advantage effect of longitudinal compression force shall be not considered if bent moment caused by longitudinal compression force is the same sign with moment caused by transversal load.

- when bearing longitudinal tensile force, determined by equation:

$$\varphi_n = -0.2\frac{N}{R_{bt}bh_0} \qquad (79)$$

But absolute value is not greater than 0.8.

Value $(1+\varphi_f+\varphi_n)$ is not greater than 1.5 in all cases.

Value Q_b is taken not less than $\varphi_{b3}(1+\varphi_f+\varphi_n)R_{bt}bh_0$ in equation (76)

Coefficient φ_{b3} is taken as the following:

- for heavy concrete and cellular concrete: 0.6

- for small particle concrete: 0.5

- for light concrete with mark on average specific mass:

+ ≥ D1900: 0.5

+ ≤ D1800: 0.4

Reinforced concrete member with transversal reinforcement should ensure strength according to inclined section in the middle space of stirrup, between support and inclined reinforcement, among reinforcements.

Shear force Q_{sw} and $Q_{s,inc}$ are determined by total projectors of correlative critical internal force in stirrup and inclined reinforcement cross dangerous crack on axis normal to member longitudinal axis.

The height c_0 of dangerous oblique crack projector on member longitudinal axis is determined from minimum condition of expression $(Q_b+Q_{sw}+Q_{s,inc})$. In equation for determining Q_b, replacing value c by c_0 , value c_0 is taken not greater than $2h_0$ and not greater than value c , c_0 is not less than $2h_0$ if $c > h_0$ at once.

For member only placing stirrup normal to member longitudinal axis, with unchanged stride in considering inclined section, value c_0 corresponding to minimum value of expression (Q_b+Q_{sw}) shall be determined by equation:

$$c_0 = \sqrt{\frac{\varphi_{b2}\left(1+\varphi_n+\varphi_f\right)R_{bt}\,bh_0^2}{q_{sw}}} \qquad (80)$$

where: q_{sw} – internal force in stirrup on each member length unit, is determined by equation:

$$q_{sw} = \frac{R_{sw}\,A_{sw}}{s} \qquad (81)$$

With such member, shear force Q_{sw} is determined by equation:

$$Q_{sw} = q_{sw}c_o \qquad (82)$$

Then, stirrup determined by calculation should satisfy the equation:

$$q_{sw} \geq \frac{\varphi_{b3}\left(1+\varphi_n+\varphi_f\right)R_{bt}\,b}{2} \qquad (83)$$

Besides, stirrup should satisfy requirements in subclauses from **8.7.5** to **8.7.7** .

When calculating structure with longitudinal reinforcements that are steel groups CIV, A-IV, A-III_B or reinforcement groups A-V, A-VI, AT-VII (use coordinately), coefficients φ_{b2}, φ_{b3} and φ_{b4} **(6.2.3.4)** should multiply with coefficient 0.8.

6.2.3.4. For reinforced concrete member without shear force stirrup, to ensure strength on oblique crack should calculate with the most dangerous oblique crack as the following equation:

$$Q \leq \frac{\varphi_{b4}\left(1+\varphi_n\right)R_{bt}\,b\,h_0^2}{c} \qquad (84)$$

Where: right side of equation (84) is taken not greater than $2.5R_bbh_0$ and not less than $\varphi_{b3}\left(1+\varphi_n\right)R_{bt}bh_0$.

Coefficient φ_{b4} is taken as the following:

- for heavy concrete, cellular concrete: 1.5

- for small particle concrete: 1.2

- for light concrete with mark on average specific mass:

- ≥ D1900: 1.2

- ≤ D1800: 1.0

Coefficients φ_{b3} and φ_n as well as values Q and c in equation (84) is determined by equation **6.2.3.3.**

If there are no cracks normal to longitudinal axis in zone considering shear force effect, it means that condition (127) is satisfied when replacing $R_{bt,ser}$ by R_{bt} , member strength calculated from condition (144) is increased by replacing $R_{bt,ser}$ and $R_{b,ser}$ by R_{bt} and R_b respectively.

6.2.3.5. Reinforced concrete members with shear force inclined compression edge (Figure 11) should be calculated according to subclauses **6.2.3.3** and **6.2.3.4** to ensure inclined section strength. In which, the height working in considering inclined section scope is taken as the following:

- for member with transversal reinforcement: value h_0 maximum;

- for member without transversal reinforcement: value h_0 medium.

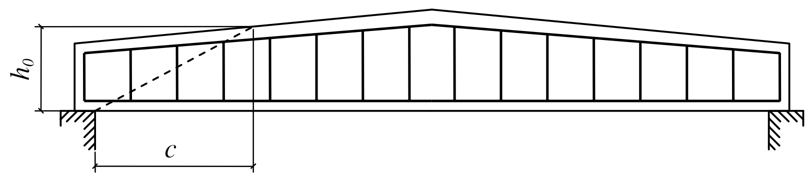


Figure 11. Calculation outline of reinforced concrete beam with inclined compression edge

6.2.3.6. To ensure strength on inclined lane compressed between effecting load and support, shear force reinforced concrete short cantilever ($l \leq 0,9h_0$, figure 12) should be calculated by equation:

$$Q \leq 0.8\varphi_{w2} R_b b l_b \sin\theta \tag{85}$$

where: the right side of equation (85) is taken not greater than $3.5R_{bt}bh_0$ and not less than the right side of equation (84); θ is sloping angle between calculated compression strip and transversal.

The width of compression inclined strip l_b is determined by equation:

$$l_b = l_{sup} \sin\theta \tag{86}$$

where: l_{sup} – the length of load transmittance along stretch-out-length of cantilever.

When determining the length l_{sup} should consider transmitting load characteristic according to different bearing support outlines of structure on console (free bearing girder or fixed beam, placed along with cantilever or perpendicular to cantilever, etc...)

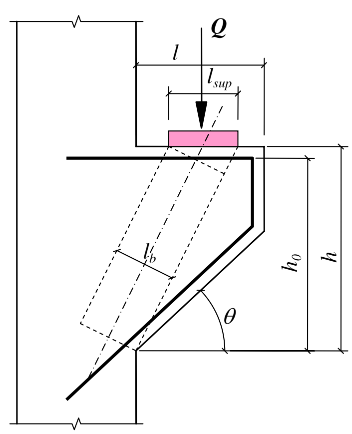


Figure 12. Short cantilever calculation outline

Consider the impact of stirrup in vertical console, φ_{w2} factor is specified in equation:

$$\varphi_{w2} = 1 + 5\alpha\mu_{w1} \qquad (87)$$

In which:

$$\alpha = \frac{E_s}{E_b};\ \mu_{w1} = \frac{A_{sw}}{bs_w};$$

A_{sw} - sectional area of stirrup reinforcements on the same plane;

s_w - spacing of stirrup reinforcements according to perpendicular directions.

Since then, transversal stirrup and stirrup inclined at an angle not greater than 45^0 are included.

Transversal reinforcement of short cantilever is placed in accordance with the provision in subclause **8.7.9.**

6.2.3.7 Reinforced concrete member bearing bending moment (Figure 13), to ensure the inclined section resistance, should be calculated with the dangerous inclined section by the following equation:

$$M \le M_s + M_{sw} + M_{s,inc} \qquad (88)$$

M moment in the equation (88) is determined by the external force from one side of inclined section to vertical axis of moment plane, through Nb resultant forces point in compression zone.

Moments M_s, M_{sw} and $M_{s,inc}$ are sum of moments for such axis as correspondent internal forces in longitudinal reinforcement, stirrup, inclined bar cross tension zone of inclined section.

Determining internal force in reinforcement cross inclined section, note the anchorage of reinforcement on the outside zone of inclined section.

Compression zone height of inclined section is determined form equilibrium condition of internal force projection in compression zone concrete and reinforcement cross tension zone of inclined section on structural longitudinal axis.

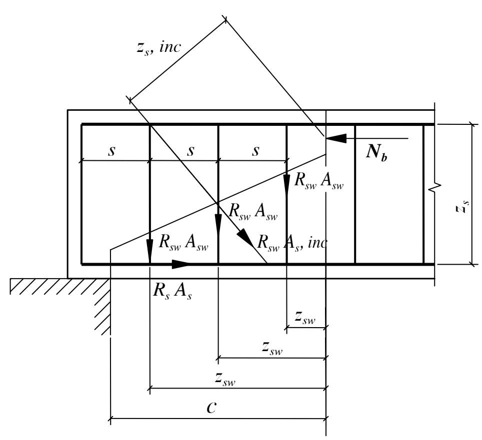


Figure 13. Internal force on inclined section with reinforced structural longitudinal axis layout when calculating bending moment resistance.

Inclined section effected by moment should be calculated at longitudinal reinforcement shearing or bending position, as well as zone near bearing support of beam and free end of cantilever. Besides, inclined section effected by moment is calculated at positions changing the shape of member suddenly (cutting a part of section, etc...).

At the position near bearing support of member, M_s bearing longitudinal reinforcements cross tension zone of inclined section is specified in Equation:

$$M_s = R_s A_s z_s \qquad (89)$$

In which:

A_s – (sectional) area of longitudinal reinforcement cutting through inclined section;

z_s - spacing of the resultant force from longitudinal reinforcement to compression zone.

If longitudinal reinforcements are not anchored, tension strength to calculate their R_s at shear position through inclined section should be permitted to decrease as item 5 table 23.

For member of cellular concrete, internal force in longitudinal reinforcement is determined as calculation only when considering the working of horizontal anchorage near bearing support.

Moment M_{sw} born by stirrups perpendicular to structural longitudinal axis, has unchanged stride in tension zone of the inclined section, is specified in Equation:

$$M_{sw} = q_{sw} \frac{c^2}{2} \qquad (90)$$

Where:

q_{sw} – internal force in stirrup per unit length, specified in Equation (81);

c – the length of the most dangerous inclined section projection on longitudinal axis of the member.

6.2.4 . Design according to durability of space section (simultaneous bent and torsion member)

6.2.4.1 . Designing space section, internal forces are determined by the following suppositions:

- Ignore tension resistance of concrete;

- Compression zone of space section is considered plane, located at an angle θ to longitudinal member, compression resistance of concrete is determined by $R_b \sin^2 \theta$, distributed evenly on compression zone;

- Tensile stress in longitudinal reinforcement and transversal reinforcement crossing tension zone of the space section is taken by the strength R_s and R_{sw};

- Stress of reinforcement on compression zone is specified by R_{sc} for intensile reinforcement; by subclause 6.2.2.5 for tensile reinforcement.

Rectangular section member

6.2.4.2 . Calculating simultaneously bending and torsion member, should satisfy equation:

$$M_t \leq 0{,}1 R_b b^2 h \qquad (91)$$

Where:

b – smaller dimension of section

h – larger dimension of section

R_b value for concrete at the higher grade of B30 is selected as B30.

6.2.4.3. Calculation of space section on strength (Figure 14) should be made as shown in equation:

$$M_t \leq R_s A_s \frac{1+\varphi_w \delta \lambda^2}{\varphi_q \lambda + \chi}\left(h_0 - 0.5x\right) \qquad (92)$$

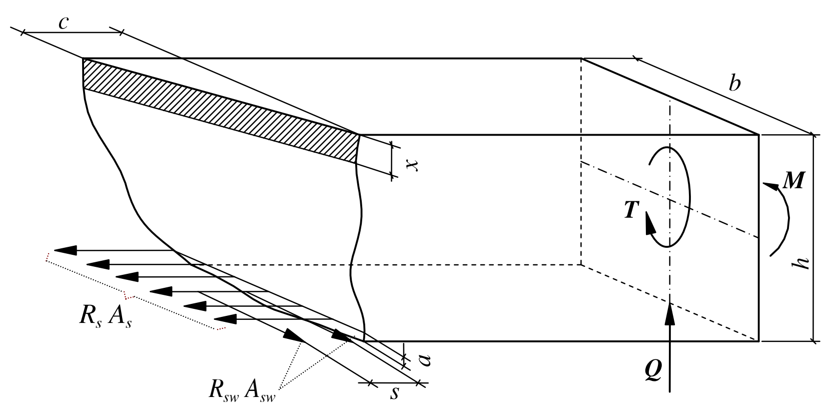


Figure 14*: Internal force outline in space section of simultaneously bending and torsion reinforcement member when calculating according to durability*

The height of compression zone x is specified in equation:

$$R_s A_s - R_{sc} A'_s = R_b bx \qquad (93)$$

The calculation should be verified with 3 outlines of compression zone position of space section:

- Outline 1: at compressed side of member as bending (Figure 15a);

- Outline 2: at side of member, parallel with bent moment plane (Figure 15b);

- Outline 3: at tensile side of member as bending (Figure 15c)

In equations (92) and (93):

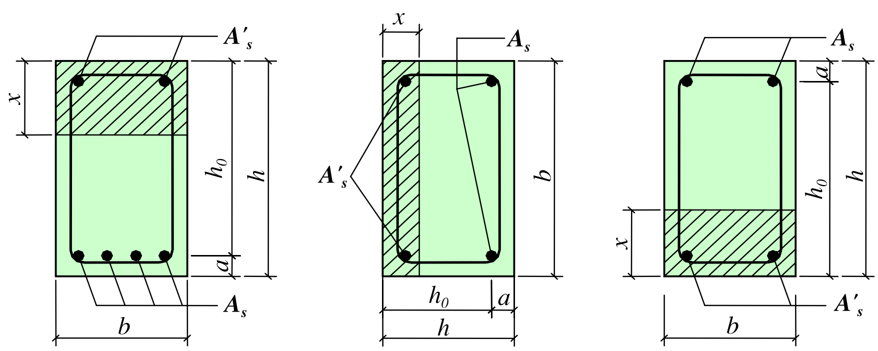
A_s, A'_s – longitudinal reinforcement section area on tension zone and compression zone as calculation outline, respectively;

b, h –dimension of member sides parallel with and perpendicular to limit line of compression zone, respectively:

$$\delta = \frac{b}{2h + b} \quad (94)$$

$$\lambda = \frac{c}{b} \quad (95)$$

Where: c – projection height of compression zone limit line on longitudinal axis of member, the calculation is verified by the most dangerous c value, c is specified by iterative method of successive approximations and not more than (2h+b).



a – at compressed side as bending; b – at side parallel with acting plane of bent moment; c – at tension side as bending

***Figure 15:** Compression zone position diagram of space section*

In equation (92), χ and φ_q values specified for internal forces relation M_t, M and Q should be taken as follows:

- without bending moment: $\chi = 0$; $\varphi_q = 1$;

- When calculating according to:

+ outline 1: $\chi = \frac{M}{M_t}$; $\varphi_q = 1$

+ outline 2: $\chi = 0$; $\varphi_q = 1 + \frac{Qh}{2M_t}$

+ outline 3: $\chi = -\frac{M}{M_t}$; $\varphi_q = 1$

Torque moment M_t, bending moment M and shear force Q are taken from section perpendicular to longitudinal axis of member and cross center of compression zone of space section.

Factor value φ_w, specified for relation between horizontal reinforcement and longitudinal reinforcement, should be taken as follows:

$$\varphi_w = \frac{R_{sw} A_{sw}}{R_s A_s} \frac{b}{s} \quad (96)$$

Where:

A_{sw} – section area of a stirrup reinforcement bar on tensile side of design outline in consideration;

s – space among those stirrups

Value φ_w is not less than:

$$\varphi_{w,\min} = \frac{0,5}{1 + M/2\varphi_w M_u} \tag{97}$$

and not more than

$$\varphi_{w,\max} = 1,5\left(1 - \frac{M}{M_u}\right) \tag{98}$$

Where:

M – bending moment, = 0 for outline 2; mark "-" for outline 3;

M_u – maximum bending moment in which the section is perpendicular to longitudinal axis of the resistant member.

If value φ_w calculated from equation (96) is less than $\varphi_{w,min}$, internal force value $R_s A_s$ given in equations (92), (93) is decreased according to the ratio $\varphi_w / \varphi_{w,\min}$.

If satisfying the condition:

$$Mt = 0.5Qb \tag{99}$$

the calculation on outline 2 should be verified as the following:

$$Q \le Q_{sw} + Q_b - \frac{3M_t}{b} \tag{100}$$

In equation (99), (100):

b – width of section side perpendicular to bent plane;

Q_{sw}, Q_b – are determined on subclause 6.2.3.3.

6.2.5. Design reinforced concrete member bearing partial load

A. Design partial compression

A. Designing partial compression

6.2.5.1. Designing partial compressed member (compression face) without transversal reinforcement should satisfy the following condition:

$$N \le \psi R_{b,loc} A_{loc1} \tag{101}$$

Where:

N – longitudinal compression force due to partial load;

A_{loc1} – partial compression area (Figure 16);

ψ - ratio, depending on distribution characteristics of partial load on faced compression area, is given as follows:

+ When load is evenly distributed: 1.0;

+ When load is unevenly distributed (below beam head, purlin, lintel):

For heavy concrete, small particle concrete, light concrete: 0.75

For cellular concrete: 0.50

$R_{b,loc}$ – compression strength on partial calculation of concrete, should be taken as follows:

$$R_{b,loc} = \alpha \varphi_b R_b \qquad (102)$$

Where: $\alpha\varphi_b \geq 1$;

+ a =1 for concrete with grade lower than B25;

+ a = 13.5 for concrete with grade B25 and over;

+ $\varphi_b = \sqrt[3]{A_{loc2} / A_{loc1}}$

But not more than the following values:

+ when force placing outline is according to on Figure 16a, c, d, e, h:

For heavy concrete, small particle concrete, light concrete:

Grade higher than B7.5: 2.5

Grade B3.5; B5; B7.5: 1.5

For light concrete and cellular concrete with grade B2.5 and lower: 1.2

+ when force placing outline is according to Figure 16b, d, g; not depending on type and grade of concrete: 1.0

R_b, R_{bt} – are taken as for concrete structure (see item 7 of table 15);

A_{loc2} – partially compressed area determined by instruction of subclause 6.2.5.2.

6.2.5.2. Design area A_{loc2} includes all areas arranged symmetrically with compressed area (Figure 16). The following conditions should be performed:

- When partial load effects over the total of width b of member, design area includes parts with width not more than b at each boundary of partial loaded area (Figure 16a);

- When partial load places at boundary on the total of width of member, design area A_{loc2} is equal to area A_{loc1} (Figure 16b);

- When partial load places at joints of purlin or beam, calculated area includes parts with the width equal to the depth joining to purlin or beam structure and the length not more than a half space between considering purlin or beam and their closest ones (Figure 16c);

- If space among beams (purlins) is more than the width of member at two times, the width of calculated area is equal to the total of width of beam (purlin) and double the width of member (Figure 16d);

- When partial load places at a corner of member (Figure 16e), calculated area A_{loc2} is equal to partially compressed area A_{loc1};

- When partial load places at a part of the length and a part of the width of member, calculated area is as in figure 16f. When there are some load with the same characteristics, calculated area is limited by lines crossing central point of space among load positions that close each other;

- When partial load places at salient of wall or piece of wall with T section, calculated section A_{loc2} is equal to partial compressed area A_{loc1} (Figure 16g);

- When determining calculated area for a complex section, no need to calculate area parts that their connection with loading zone is not assured with necessary reliability (Figure 16h).

Note: With partial load due to beam, purlin, lintel and other bending members, when determining A_{loc1} and A_{loc2}, the depth from the edge of bearing support is not greater than 20 cm.

6.2.5.3. Partial compressed calculation of members made from heavy concrete which were indirectly placed reinforcement in steel fabric form should satisfy the following equation:

$$N \le R_{b,red} \; A_{loc1} \qquad (103)$$

Where:

A_{loc1} – partial compressed area;

$R_{b,red}$ – converted prism strength of concrete, when calculating partial compression, should be taken as follows:

$$R_{b,red} = R_b \, \varphi_b + \varphi \, \mu_{xy} \, R_{s,xy} \, \varphi_s \qquad (104)$$

Where: $R_{s,xy}$, φ, μ_{xy} - symbols as in subclause 6.2.2.13.

$$\varphi_b = \sqrt[3]{A_{loc2} / A_{loc1}} \qquad (105)$$

But not greater than 3.5

φ_s – coefficient considering indirect reinforcement area in partial compressed zone, φ_s = 1 for outline figure 16b, e, g; in which indirect reinforcement is calculated in the condition that transversal steel grid should be placed on area not less than the area limited by discontinuous line on the corresponding outline of figure 16; for outline of figure 16a , c, d, f, coefficient φ_s is determined as follows:

$$\varphi_s = 4.5 - 3.5\frac{A_{loc1}}{A_{ef}} \qquad (106)$$

Where: A_{ef} –area of concrete on limit zone by the outer bars of steel grid used for indirect reinforcement, and should meet the following condition:

$A_{loc1} < A_{ef} \leq A_{loc2}$

B. Pierced compression calculation

6.2.5.4. Plate structure (not placed transversal reinforcement) effected by evenly distributed force on limited area should calculated pierced compression in the following equation:

$$F \leq \alpha R_{bt} u_m h_0 \qquad (107)$$

Where:

F – pierced compression force;

α – coefficient, applied for:

+ Heavy concrete: 1.0

+ Small particle concrete: 0.85

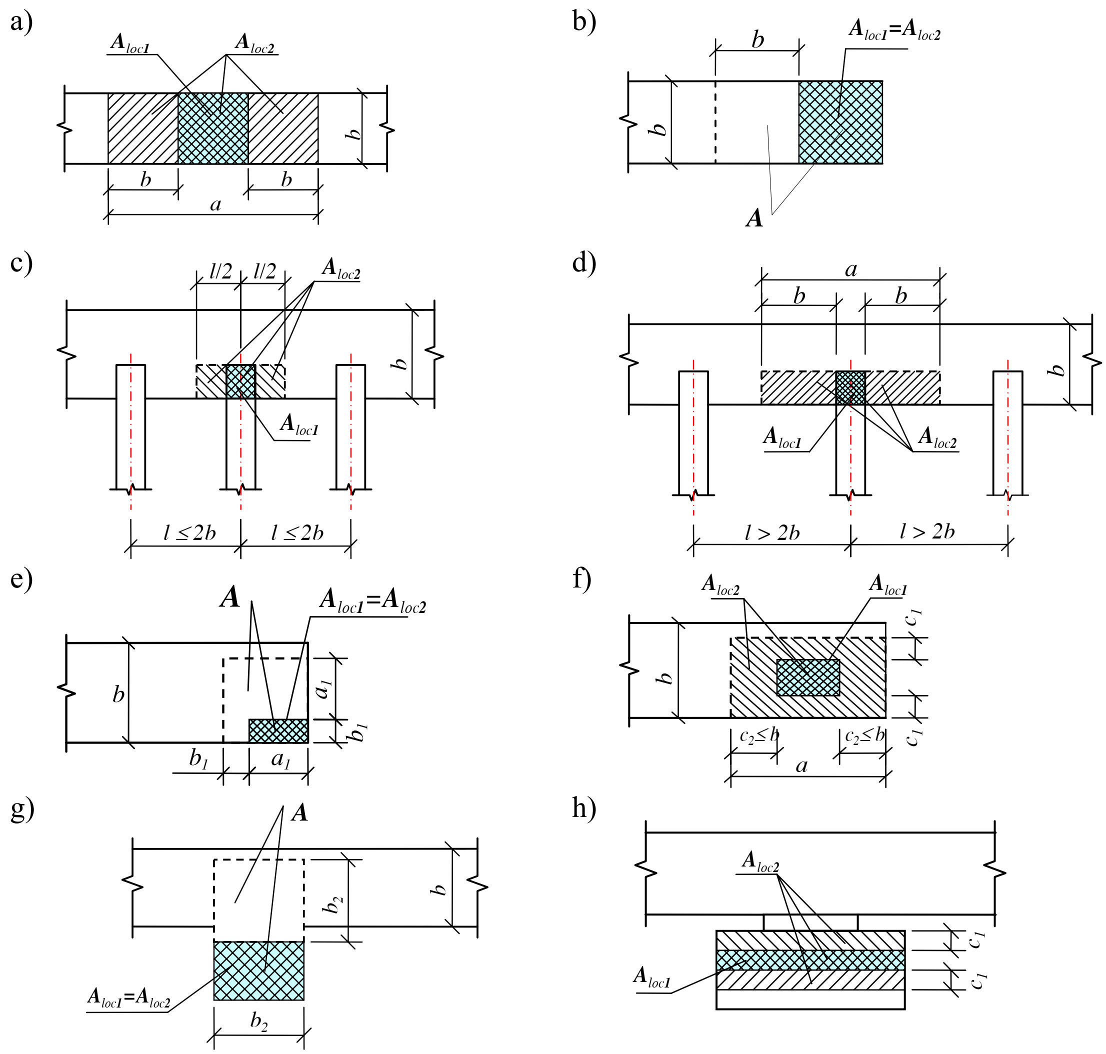
+ Light concrete: 0.8

u_m – average value of upper bottom perimeter and lower one of pierced compression tower formed when compressed, in the scale of working section height.

When determining u_m and F, supposed that pierced compression happened on the inclined plane of tower with small bottom is forced area, and other sides are at 450 inclined planes in comparison with the horizontal plane (Figure 17a).

Pierced compression force F is taken as force effected on tower, subtract anti-pierced compressed load effected on larger bottom of pierced owner (taken from plane that placed tension reinforcement).

If due to bearing support outline, pierced compression only happens with over 45^0 inclined side plane of tower (e.g: in grillage figure 17b), the right item of condition (107) is determined for actual pierced compressed tower multiplying with h_0/c. At that time, this force should not be greater than the value corresponding to pierced compressed tower c = $0.4h_0$, where c is the length of projection of the tower's side on horizontal plane.



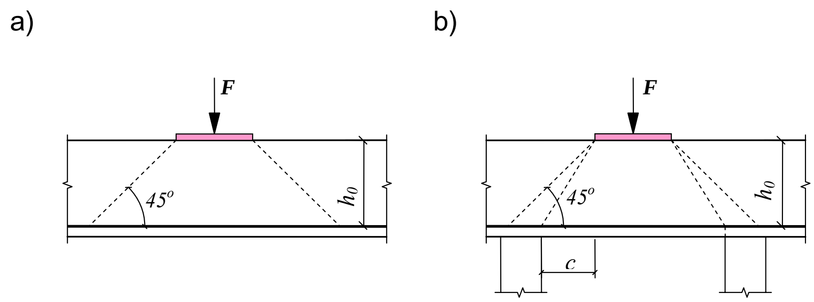
a) Partial load placed at total width of member; b) Partial load placed at total width of member boundary; c, d) Partial load placed at setting purlin or beam position; e) Partial load placed at a corner of member; f) Partial load placed at a part of member width and a part of member length or at salient of wall or piece of wall; g) Partial load placed at wall pier; h) Complex section

Note: A_{loc1} – partial compressed area;

A_{loc2} – partial compressed calculated area;

A – minimum area should be placed on steel grid, where indirect reinforcement is mentioned in calculation according to equation (104).

Figure 16: Calculated outline of partial compressed reinforced concrete member



a) the side of pierced compression tower is 45^0 inclined plane, b) the side of pierced compression tower is over 45^0 inclined plane

Figure 17. Pierced compression design outline of reinforced concrete member.

When within the limit of pierced compressed tower with placing stirrups perpendicularly to plate, the calculation should be given by equation:

$$F \leq F_b + 0.8\,F_{sw} \qquad (108)$$

But not greater than $2F_b$.

Internal force Fb is taken by the right item of equation (107), F_{sw} - total shear force that stirrup (cutting the side planes of tower) are bearing, specified as follows:

$$F_{sw} = \sum R_{sw} A_{sw} \qquad (109)$$

Where: R_{sw} should not exceed the value corresponding to CI, A-I reinforcement.

When mentioning to transversal reinforcement, F_{sw} should not be less than $0.5F_b$.

When arranging stirrup on a limit part near concentrated load position, it should calculate more according to condition (107) for pierced compressed tower with upper bottom on perimeter of transversal reinforced part.

Transversal reinforcement should meet the conditions in subclause 8.7.8

C. Jerk calculation

6.2.5.5. Reinforcement member jerked by the load action at lower side or within the scale of section's height (figure 18) should be taken as follows:

$$F\left(1 - \frac{h_s}{h_0}\right) \leq \sum R_{sw} A_{sw} \qquad (110)$$

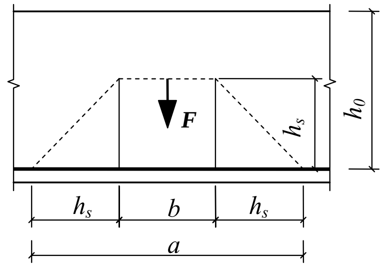


Figure 18. Jerk calculation outline of reinforcement member

Where:

F – jerked force;

h_s – space from position placing jerked force to central point of longitudinal reinforcement section;

$\sum R_{sw} A_{sw}$ – total shear force due to stirrup reinforcement auxiliary placed on jerked zone with the length a.

$$a = 2h_s + b \qquad (111)$$

Where: b – width of area transmitting jerked force.

The value h_s and b are defined depending on characteristics and condition placing jerked load on member (at cantilever, or continuous members, etc...)

D. Calculating breakdown girder

6.2.5.6. When the sunken part of breakdown girder is on tension zone, transversal reinforcement should be placed enough to bear:

a) Resultant forces in longitudinally tensile reinforcement without anchor to compression zone:

$$F_1 = 2R_s A_{s1} cos\frac{\beta}{2} \qquad (112)$$

b) 35% resultant forces in all longitudinally tensile reinforcement bars:

$$F_2 = 0{,}7R_s A_{s1} cos\frac{\beta}{2} \qquad (113)$$

Transversal reinforcement required as calculation from above conditions should be arranged in such a way that with the length $s = h\,tg\frac{3}{8}\beta$ (figure 19).

Total projection of resultant forces effected by transversal reinforcement bars (stirrups) on bisector of sunken angle should not be less than (F1 + F2), meaning that:

$$\sum R_{sw} A_{sw} \cos\theta \geq (F_1 + F_2) \qquad (114)$$

In equations from (112) to (114):

A_s – transversal section area of total tension longitudinal reinforcement bars;

A_{s1} – transversal section area of total tension longitudinal reinforcement bars without anchor to compression zone;

β - sunken angle in tension zone of member;

$\sum R_{sw}$ – total section areas of transversal reinforcement in scale s;

θ - inclined angle between transversal reinforcement bars and bisector of angle β;

Note 1: Transversal reinforcements should brace all tension longitudinal reinforcement and tightly anchor to compression zone;

Note 2: When $\beta \geq 160^o$, tension longitudinal reinforcement can be continuously arranged. When $\beta < 160^o$, some or all tension longitudinal reinforcements should be separated and anchored to compression zone.

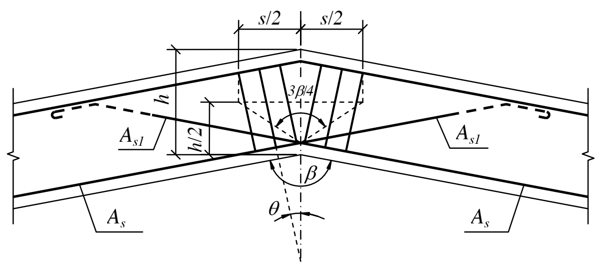


Figure 19. Calculation and structure of breakdown girder

6.2.6. Calculating preset details

6.2.6.1. Anchors bars directly welded to plane steel plate of preset details, effected by bent moment M, force N normal to them, and slipping force Q of static load placed on symmetrical plane of preset details (figure 20), should be calculated as follows:

$$A_{an} = \frac{1{,}1\sqrt{N_{an}^2 + \left(\frac{Q_{an}}{\lambda\delta}\right)^2}}{R_s} \qquad (115)$$

In which:

A_{an} – total section areas of anchor bars at maximum forced anchor row;

N_{an} – maximum tension force in one row of anchor bar:

$$N_{an} = \frac{M}{z} + \frac{N}{n_{an}} \qquad (116)$$

Q_{an} – slipping force for one row of anchor bar:

$$Q_{an} = \frac{Q - 0.3N'_{an}}{n_{an}} \qquad (117)$$

N'_{an} - maximum compression force in one row of anchor bar, should be defined as follows:

$$N'_{an} = \frac{M}{z} - \frac{N}{n_{an}} \qquad (118)$$

In equations from (115) to (118): M, N, Q – moment, longitudinal, slipping forces effected on preset details; moment should be determined for axis on edge plate plane and cross central point of all anchor bars;

n_{an} – row number of anchor bar longitudinal to slipping force direction; if not ensuring slipping force Q distributed for all anchor bars, only not more than 4 anchor rows should be mentioned when determining slipping force Q_{an}.

z – space between outer rows of anchor bar;

λ - coefficient, defined according to the equation (119) when anchor bars have diameter from 8mm to 25mm, for heavy concrete, small particle concrete of grade from B12.5 to B50 and light concrete grade from B12.5 to B30, λ is specified by the following equation:

$$\lambda = \frac{4{,}75\sqrt[3]{R_b}}{\left(1 + 0{,}15A_{an1}\right)\sqrt{R_s}}\beta \qquad (119)$$

But should not taken over 0.7 ; coefficient λ is taken as the same of grade B50 for heavy concrete and small particle of grade over B50; light concrete of grade over B30 is taken as the same of grade B30;

Where: R_b and R_s is by MPa;

A_{an1} – section area of anchor bar at the biggest tension row, cm^2;

β - coefficient, determined as following:

+ For heavy concrete: 1.0

+ For small particle concrete: group A: 0.8; group B,C: 0.7

+ For light concrete: $\rho_m/2300$ (ρ_m - average volumetric mass of concrete, kg/m^3);

δ - coefficient, defined as follows:

$$\delta = \frac{1}{\sqrt{1 + \omega}} \qquad (120)$$

But should not below 0.15

Where:

$$\omega = 0.3\frac{N_{an}}{Q_{an}} \text{ if } N'_{an} > 0 \text{ (compressed)}$$

$$\omega = 0.6\frac{N}{Q} \text{ if } N'_{an} \leq 0 \text{ (uncompressed)}$$

If there is no tension force in anchor bars, coefficient δ is equal to 1.

Section area of anchor bars in the others is equal to section area of the maximum tension row.

In the equations (116) and (118), force N is positive if directing from preset details to outside (figure 20), is negative if directing into preset details. If force N_{an}, N'_{an} and slipping force Q_{an} defined in equations from (116) to (118) are negative, in equations from (115) to (117) and (120) it is equal to 0. Besides, if $N_{an} < 0$, so $N'_{an} = N$ in equation (117).

When arranging preset details in the upper plane of member (when pouring the concrete), coefficient λ is decreased 20% and $N'_{an} = 0$.

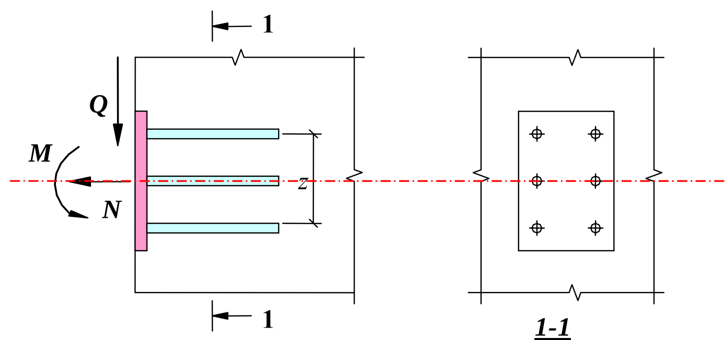


Figure 20. **Outline of internal force effected on preset details**

6.2.6.2. In preset details with anchor bars welded with from 15^0 to 30^0 angle, these bars shall be defined to slipping force as follows (when Q>N, N is jerked force), as follows:

$$A_{an,inc} = \frac{Q - 0.3N'_{an}}{R_s} \qquad (121)$$

Where:

$A_{an,inc}$ – total section area of inclined anchor bars;

N'_{an} – see subclause 6.2.6.1.

Then placing more normal anchor bars, calculated by equation (115) with $\delta = 1$, Q_{an} is taken equal to 10% slipping force value determined in equation (117).

6.2.6.3. Structure of connection details should ensure that anchor bars work as the calculation outline. All details outside the preset details and welded details should be calculated according to steel structure design standards TCXDVN 338:2005. When calculating jerked force resistant plate and code plate, considering that they connect correctly with normal anchor bars. Besides, the plate thickness of preset details welded with anchor bars should be tested according to the following condition:

$$t \geq 0,25\, d_{an} \frac{R_s}{R_{sq}} \qquad (122)$$

Where:

d_{an} – required diameter of calculated anchor bar;

R_{sq} – calculated shear resistant strength of steel plate, according to TCXDVN 338:2005.

In the case that weld connection used to increase the working zone of plate when anchor bars are pulled out of plate and there are corresponding basics, the condition (112) can be adjusted for that weld connection.

The plate thickness should satisfy all requirements of weld technology.

6.3. Designing fatigue reinforcement member

6.3.1. Design of fatigue reinforcement member should be implemented by comparing stress in concrete and reinforcement with corresponding fatigue limit $\sigma_{b,fat}$ and $\sigma_{s,fat}$.

Fatigue limit of concrete $\sigma_{b,fat}$ is taken as the calculation strength of the reinforcement R_s which is multiplying with working coefficient of concrete γ_{b1} (γ_{b1} is taken according to table 15).

Fatigue limit of reinforcement $\sigma_{b,fat}$ is taken as the calculation strength of the reinforcement R_s multiplying with working coefficient of concrete γ_{s3} (γ_{s3} is taken according to table 24). In the case that using welded connection reinforcement, fatigue limit value $\sigma_{s,fat}$ may further mention to working coefficient γ_{s4} (γ_{s4} is taken according to table 25).

Stress in concrete and reinforcement is calculated as to elastic objects (according to conversion section) effected by external force and pre-compression force P.

Inelastic deformation in compression zone of concrete is mentioned by decreasing elastic modulus of concrete, taking conversion coefficient from steel to concrete α' is 25, 20, 15, 10 corresponding to concrete grade of B15, B25, B30, B40 and higher.

Coefficient $\alpha' = E_s/E'_b$, where: E'_b - conventional elastic modulus of concrete effected by repeated load. E'_b is different with Eb, it is specific for ratio between stress and total deformation (including elastic deformation and residual deformation) of concrete, assembled from loaded process.

In the case that the condition (143) is not satisfied when the value $R_{bt,ser}$ is replaced by R_{bt}, conversion section area is determined no concerning tensile zone of concrete.

6.3.2 . Calculation of fatigue member on section perpendicular to longitudinal axis of member should be calculated according to the following condition:

- For compression concrete:

$$\sigma_{b,\max} \leq \sigma_{b,fat} = R_b \gamma_{b1} \quad (123)$$

- For tensile reinforcement:

$$\sigma_{s,\max} \leq \sigma_{s,fat} = R_s \gamma_{s3} \quad (124)$$

In equations (123), (124):

$\sigma_{b,\max}$, $\sigma_{s,\max}$ - maximum normal stresses in compression concrete and tensile reinforcement, respectively.

R_b – concrete calculation strength;

Rs – tensile reinforcement calculation strength

When there is reinforcement weld connection, in the equation (124): $\sigma_{s,fat} = R_s \gamma_{s3} \gamma_{s4}$

It is necessary to avoid the appearance of tensile stress when having action of repeated load in compression concrete tested zone.

Compression reinforcement is not necessary to calculate fatigue.

6.3.3. Fatigue calculation on inclined section should be performed in condition: transversal reinforcement bearing total resultant forces of main tensile stress effect along the length of member at center point of a convert section level, then stress on transversal reinforcement is taken by calculation strength R_s multiplying with working condition coefficient γ_{s3} and γ_{s4} (table 24 and 25).

For member without transversal reinforcement, requirements of subclause 7.1.3.1 should be obeyed, but in equations (144) and (145) correlatively replacing concrete calculation strength $R_{bt,ser}$ and $R_{b,ser}$ by calculation strength R_{bt} and R_b which was multiplied with working condition coefficient γ_{b1} in table 16.

7. Calculating reinforcement member according to the second limit states

7.1. Calculating concrete member according to crack forming

7.1.1. General principle:

Reinforced concrete member is calculated according to crack forming:

- Normal to longitudinal axis of member;

- Inclined with longitudinal axis of member.

7.1.2. Calculating the crack forming normal to longitudinal axis of member.

7.1.2.1 . For eccentric compression, tensile, moment reinforcement, internal force on normal section when forming crack is determined by the following supposition:

- Section is considered plane after deformed

- The maximum relative elongation of outer tensile concrete fiber is equal to $2R_{bt,ser}/E_b$;

- Determined stress in compression zone concrete (if any) mentions to elastic or inelastic deformation of concrete. Then inelastic deformation is mentioned by decreasing space of core r (space from center point of convert section to farthest core point of tension zone), see subclause 7.1.2.4;

- Stress in tensile zone concrete is distributed evenly and their value is $R_{bt,ser}$;

- Stress in non-tension reinforcement is the sum of stresses, corresponding to deforming increment of covering concrete, and stress caused by shrinkage and creep of concrete.

- Stress in tension reinforcement is the sum of their pre-stress (including all losses) and stress correlative deforming increment of covering concrete.

The instructions in this subclause are not applied for repeated load members (see subclause 7.2.1.9).

7.1.2.2. When determining internal force in tension reinforcement member section without anchor, on the length of stress transmission section l_p (see subclause 5.2.2.5) when calculating according to crack forming, it should mention to the decrease of pre-stress in reinforcement σ_{sp} and σ'_{sp} by multiplying with coefficient γ_{s5} in item 5 of table 23.

7.1.2.3. Calculating reinforced concrete member with centric compression pre-stress, centric tensile N should be calculated in accordance with the following condition:

$$N \leq N_{crc} \qquad (125)$$

Where:

N_{crc} – internal force on section normal to longitudinal axis when forming crack, should be specified in equation:

$$N_{crc} = R_{bt,ser}\left(A + 2\alpha A_s\right) + P \qquad (126)$$

7.1.2.4 . Calculating bending, eccentric compression and eccentric tension member according to crack forming should be taken in accordance with the following condition:

$$M_r \leq M_{crc} \qquad (127)$$

Where:

M_r – moment due to external force on a side of considering section for axis parallel with neutral axis and cross to core point which is farthest from tension zone of this section;

M_{crc} – anticrack moment of section normal to longitudinal axis of member when forming crack, calculated by equation:

$$M_{crc} = R_{bt,ser} W_{pl} \pm M_{rp} \qquad (128)$$

Where:

M_{rp} – moment by force stress P with axis used for the determination of M_r; sign of moment is specified on turn direction ("plus" sign when the direction of M_{rp} is opposite to the direction of M_r, "minus" when they concur with each other).

Force stress P is considered as:

+ For pre-stress member: compressed external force;

+ For non-pre-stress member: tensile external force and determined as equation (8), where the value of σ_s and σ'_s in non-tensile reinforcement are taken by loss value due to shrinkage of concrete according to item 8 of table 6 (the same with pre-tensile reinforcement on platform);

Value M_r is calculated as follows:

- For bent member (figure 21a):

$$M_r = M \qquad (129)$$

- For eccentric compression member (figure 21b):

$$M_r = N(e_0 - r) \qquad (130)$$

- For eccentric tension member (figure 21c):

$$M_r = N(e_0 + r) \qquad (131)$$

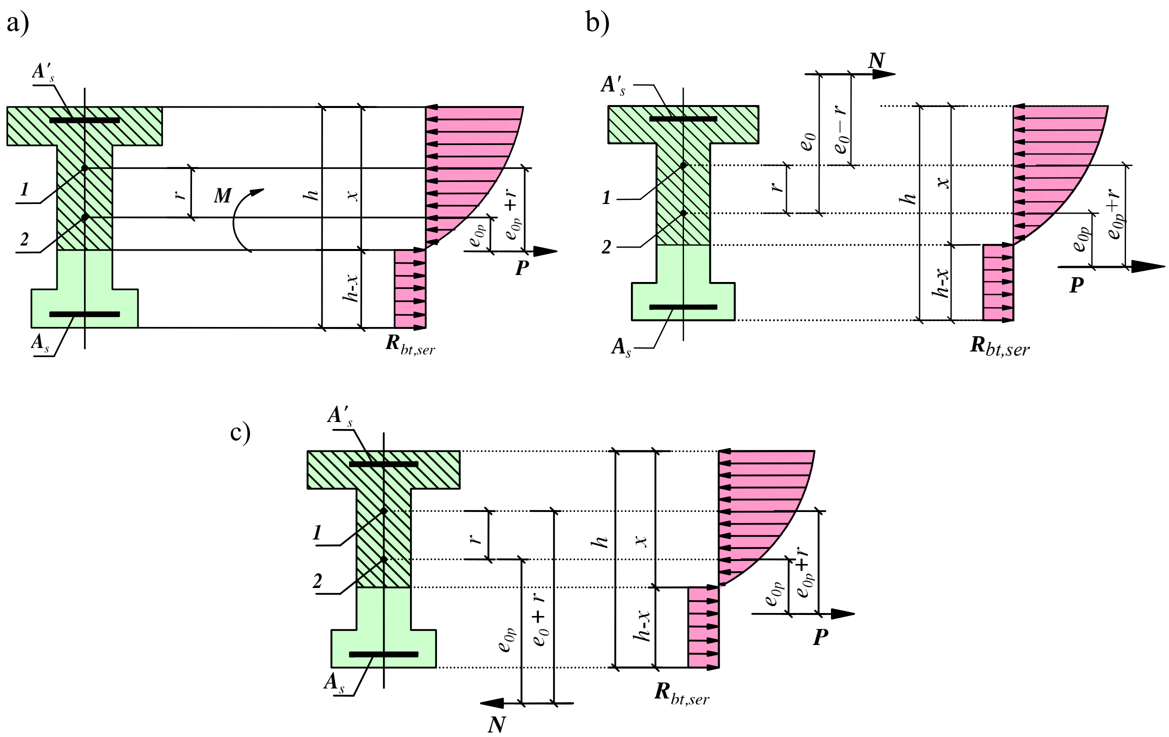
Value M_{rp} is calculated as the following:

- When calculating according to crack forming on tension section zone due to external force, but compressed by pre-compression force (figure 21), determined as follows:

$$M_{rp} = P\left(e_{0p} + r\right) \qquad (132)$$

- When calculating according to crack forming on tension zone of section due to pre-compression force (figure 22), determined as follows:

$$M_{rp} = P\left(e_{0p} - r\right) \qquad (133)$$



a – bending; b –eccentric compression; c –eccentric tension

Note:

1- core point;

2- center point of conversion section

***Figure 21:** Outline of internal force and stress sketch on transversal section of member when calculating according to crack forming normal to longitudinal axis in tension zone due to external force, but compressed by pre-compression force.*

In equations form (130) to (133):

r – space from center point of convert section to core point which is farthest from tension zone and being tested crack forming:

+ For eccentric compression member, eccentric tension and bent pre-stress member, if they satisfy the condition:

$$N \geq P \qquad (134)$$

the value r is determined as follows:

$$r = \varphi \frac{W_{red}}{A_{red}} \qquad (135)$$

+ For eccentric tension member, if they don't satisfy the condition (134), the value r is determined as follows:

$$r = \frac{W_{pl}}{A + 2\alpha\left(A_s + A_s^{'}\right)} \qquad (136)$$

+ For bending member without tension reinforcement, r is determined as follows:

$$r = \frac{W_{red}}{A_{red}} \qquad (137)$$

In equations (135) and (136):

$$\varphi = 1.6 - \frac{\sigma_b}{R_{b,ser}} \qquad (138)$$

But the value taken is not greater than 1.0 and not less than 0.7;

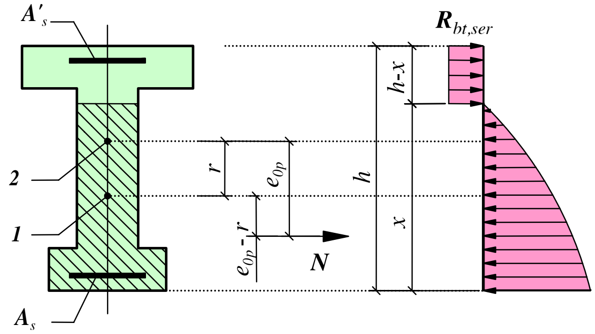
Where:

σ_b - maximum stress in compression zone of concrete due to external force and pre-stress, is calculated as to elastic object of conversion section;

W_{pl} – determined as instruction of subclause 7.1.2.6;

$\alpha = E_s / E_b$

For connection sections of composite structure and block structure without glue in joint, when calculating them according to crack forming (beginning to widening joint), value $R_{bt,ser}$ is taken equal to zero in equation (126) and (128).



Note

1- core point;

2- center point of conversion section

Figure 22: Outline of internal force and stress sketch on member section when calculating according to crack forming normal to longitudinal axis in tension zone due to pre-compressive stress.

7.1.2.5 . When calculating according to crack forming on parts with initial crack at compression zone (see subclause 4.2.9), value M_{crc} determined in equation (128) for tension zone due to external force should be decreased a quantity $\Delta M_{crc} = \lambda M_{crc}$.

Coefficient λ is determined as follows:

$$\lambda = \left(1.5 - \frac{0.9}{\delta}\right)(1 - \varphi_m) \qquad (139)$$

If Value λ taken is negative, taking equal to zero.

In equation (139):

φ_m - is determined by equation (171) for zone with initial cracks, but not greater than 0.45.

$$\delta = \frac{y}{h - y} \frac{A_s}{A_s + A_s'} \qquad (140)$$

But not greater than 1.4

Where: y – space from center point of conversion section to outer tensile concrete fiber due to external force.

For structure from fiber steel and bar steel group A-VI, A_T-VII, value δ taken by equation (140) is decreased to 15%.

7.1.2.6. Bending resistance moment Wpl of conversion section for outer tensile fiber (including inelastic deformation of concrete in tensile zone) is determined by equation (141) with supposition of no longitudinal force N and pre-compression stress P:

$$W_{pl} = \frac{2\left(I_{b0} + \alpha I_{s0} + \alpha I'_{s0}\right)}{h - x} + S_{b0} \qquad (141)$$

Position of neutral axis is determined by condition:

$$S'_{b0} + \alpha S'_{s0} - \alpha S_{s0} = \frac{(h-x) A_{bt}}{2} \qquad (142)$$

7.1.2.7. In structures reinforced by pre-stress members (e.g: bar), when determining internal force on section of that member according to crack forming, section area of tension concrete zone without prestress is excluded in calculation.

7.1.2.8 . When testing ability that structure is disable to bear force as well as crack forming (see subclause 4.2.10), internal force of section at crack forming time is specified by equation (126) and (128), but replace $R_{bt,ser}$ with $1.2R_{bt,ser}$ and coefficient γ_{sp} is equal to 1 (see subclause 4.3.5).

7.1.2.9 . Calculation according to crack forming when bearing repeated load should be taken as follows:

$$\sigma_{bt} \le R_{bt,ser} \qquad (143)$$

Where: σ_{bt} - maximum (normal) tensile stress in concrete, is specified by subclause 6.3.1.

Calculation tensile strength of concrete $R_{bt,ser}$ in equation (143) should include working condition coefficient γ_{b1} taken from table 16.

7.1.3. Calculating according to inclining crack forming with longitudinal axis of member

7.1.3.1 . Calculation according to inclining crack forming should be taken by equation:

$$\sigma_{mt} \le \gamma_{b4} R_{bt,ser} \qquad (144)$$

Where:

γ_{b4} - working condition coefficient of concrete (table 15), is specified by equation:

$$\gamma_{b4} = \frac{1 - \sigma_{mc} / R_{b,ser}}{0.2 + \alpha B} \qquad (145)$$

But not greater than 1.0;

Where:

α – coefficient, is taken for:

+ heavy concrete: 0.01;

+ small particle concrete, light concrete and cellular concrete: 0.02

B – compressive resistance grade of concrete, MPa.

Value αB taken not less than 0.3.

Main compression and tensile stress value in concrete σ_{mt} and σ_{mc} are specified by equation:

$$\sigma_{mt(mc)} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad (146)$$

Where:

σ_x - normal stress of concrete on section perpendicular to longitudinal axis caused by external force and pre-compression stress;

σ_y - normal stress of concrete on section parallel with longitudinal axis due to partial effect of reaction at support, concentrated force and distributed load as well as compression force caused by pre-stress of stirrup and inclined reinforcement;

τ_{xy} - tangential stress in concrete due to external force and compression force caused by pre-stress of inclined reinforcement.

Stresses σ_x, σ_y and τ_{xy} are determined the same with elastic objects, excluding tangential stress caused by torsion moment which is determined by the same equation with plastic state of member.

Stresses σ_x, σ_y in equation (146) are taken "plus" mark for tensile stress and "minus" mark for compression stress. Stress σ_{mc} s in equation (145) is taken according to absolute value.

Testing according to condition (144) is performed at center point of conversion section and at positions that compression flange connect to rib of member with T or I section.

When calculating member using tension reinforcement without anchor, the decrease of pre-stress σ_{sp} and σ'_{sp} on the length of stress transmitting stage l_p (see subclause 5.2.2.5) should be considered by multiplying with coefficient γ_{s5} (item 5 of table 23).

7.1.3.2. When repeated load acts, the calculation of crack forming should be implemented by instructions in subclause 7.1.3.1, among them calculation intensity of concrete $R_{bt,ser}$ and $R_{b,ser}$ concerning working condition coefficient γ_{b1} is taken according to table 16.

7.2. Calculating reinforcement concrete member according to crack widening.

7.2.1. General principle

Reinforced concrete member is calculated by crack widening:

- Normal to longitudinal axis;

- Inclined with longitudinal axis.

7.2.2. Calculation according to crack widening normal to longitudinal axis

7.2.2.1. The width of crack normal to longitudinal axis a_{crc}, mm, is specified by equation:

$$a_{crc} = \delta \varphi_l \eta \frac{\sigma_s}{E_s} 20\left(3.5 - 100\mu\right)\sqrt[3]{d} \qquad (147)$$

Where:

δ - coefficient, is taken for:

+ Bending resistance and eccentrically compressive member: 1.0

+ Tensile member: 1.2

φ_l - coefficient, taken when there are action of:

+ Temporary load in short-term and short effect of permanent load and temporary load in long-term: 1.00

+ Repeated load, permanent load and temporary load in long-term for structure made from:

- Heavy concrete:

In natural moisture condition: 1.6-15 μ

In water saturation state: 1.20

When water and dry saturation state change in shifts: 1.75

- Small particle concrete:

Group A: 1.75

Group B: 2.00

Group C: 1.50

- Light concrete and hollow concrete: 1.50

- Cellular concrete: 2.50

Value φ_l for small particle concrete, light concrete, hollow concrete, cellular concrete in water saturation state are multiplied with coefficient 0.8; and when water and dry saturation state changing in shifts, is multiplied with coefficient 1.2;

η - coefficient, is taken as the following:

+ For bar reinforcement with edge: 1.0

+ For plain round bar reinforcement: 1.3

+ For fiber reinforcement with edge or cable: 1.2

+ For plain reinforcement: 1.4

σ_s - stress in reinforcement bar S at the outer layer or (having pre-stress) stress increment due to external force is specified by instruction of subclause 7.2.2.2;

μ - reinforcement content of section: is equal to ratio between reinforcement area S and concrete section area (with working height h_0 and not including compression side) but not greater than 0.02;

d – reinforcement diameter, mm.

For member required crack resistance grade 2, the width of crack is determined by total permanent load, temporary load in long term and temporary load in short term with coefficient $\varphi_l = 1{,}0$.

For member required crack resistance grade 3, the width of crack in long term is determined by effect of permanent load, temporary load in long term with coefficient $\varphi_l > 1{,}0$. The width of crack in short term is determined by width of crack in long term and crack width increment due to temporary load in short term with coefficient $\varphi_l = 1{,}0$;

Crack width specified by equation (147) is adjusted again in the following case:

a) If section's center point of reinforcement bars S outer layer of bent, eccentric compression, eccentric tensile member with $e_{0,tot} \geq 0{,}8h_0$, is far from tensile fiber a maximum space $a_2 > 0{,}2h$, value a_{crc} should be increase by multiplying with coefficient δ_a

$$\delta_a = \frac{20\dfrac{a_2}{h} - 1}{3} \qquad (148)$$

But the value is not greater than 3.

b) For bent, eccentric compression member from heavy concrete and light concrete with $\mu \leq 0{,}008$ and $M_{r2} < M_0$, crack width due to short effect of all load is specified by linear interpolation between value

a_{crc} = 0 corresponding to crack moment M_{crc} and value a_{arc} determined by this subclause's instruction corresponding to moment $M_0 = M_{crc} + \psi bh^2 R_{bt,ser}$, (among them $\psi = 15\mu\alpha/\eta$), but not greater than 0.6. Then long term crack width due to permanent load and long term temporary load is specified by multiplying obtained value a_{crc} due to all effect load with ratio $\varphi_{l1}(M_{r1} - M_{rp})/(M_{r2} - M_{rp})$ in which $\varphi_{l1} = 1{,}8\varphi_l(M_{crc}/M_{r2})$ but not greater than φ_l .

Where:

μ, η - the same in equation (147);

M_{r1}, M_{r2} – corresponding moments M_r due to effect of permanent load, long term temporary load and due to all load (see subclause 7.1.2.4).

c) For member from light concrete and porous concrete grade B7.5 and lower, value a_{crc} should increase 20%.

7.2.2.2. Stress in tensile reinforcement (or stress increment) σ_s should be determined by equations for:

- Centric tension member:

$$\sigma_s = \frac{N - P}{A_s} \qquad (149)$$

- Bent member:

$$\sigma_s = \frac{M - P(z - e_{sp})}{A_s\, z} \qquad (150)$$

- Eccentric compression member, as well as eccentric tension when $e_{o,tot} \geq 0{,}8h_0$:

$$\sigma_s = \frac{N(e_s \pm z) - P(z - e_{sp})}{A_s\, z} \qquad (151)$$

For eccentric tension member when $e_{0,tot} < 0{,}8h_0$, value σ_s should be determined by equation (151) with z = z_s (in which: z_s – space between center points of reinforcement S and S').

Value of pre-compression stress P should be taken zero for unprestressed member. "Plus" mark is taken for eccentric tension, "minus" mark is taken for eccentric compression in equation (151). When the position of longitudinal tensile force N is between center points of reinforcement S and S', value e_s is taken "minus" mark.

In equations (150) and (151):

z – space from center point of reinforcement section area S to point of application of resultant forces on compression zone of concrete section over crack, is specified by subclause 7.4.3.2;

When tensile reinforcement is arranged a lot of layer according to the height of section in bent, eccentric compression, eccentric tension member with $e_{0,tot} \geq 0,8h_0$, stress σ_s calculated by equations (150) and (151) should multiply with coefficient δ_n :

$$\delta_n = \frac{h - x - a_2}{h - x - a_1} \qquad (152)$$

Where:

$x = \xi h_0$, with value ξ is determined by equation (164);

a_1, a_2 – space from section area center point of all reinforcement S and outer reinforcement layer to maximum tensile concrete fiber, respectively.

Stress value ($\sigma_s + \sigma_{sp}$) when there are a lot of tensile reinforcement layer ($\delta_n \sigma_s + \sigma_{sp}$) should not exceed Rs,ser.

On member stages that have initial crack on compression zone (see subclause 4.2.9), pre-compression stress value P should decrease a quantity ΔP determined by equation:

$$\Delta P = \lambda P \qquad (153)$$

In which λ is determined by equation (139).

7.2.2.3. The depth of initial crack h_{crc} on compression zone (see 4.2.9) is not greater than $0.5h_0$. Value h_{crc} is determined by equation:

$$h_{crc} = h - (1,2 + \varphi_m)\xi h_0 \qquad (154)$$

Value ξ is determined by equation (164), φ_m is calculated by equation (171) for initial crack zone.

7.2.3. Calculation according to oblique crack widening with longitudinal axis.

7.2.3.1. Oblique crack width when stirrup is normal to longitudinal axis should be specified by equation:

$$a_{crc} = \varphi_l \frac{0,6\sigma_{sw} d_w \eta}{E_s \dfrac{d_w}{h_0} + 0,15 E_b (1 + 2\alpha \mu_w)} \qquad (155)$$

Where:

φ_1 - coefficient, is taken as the following:

+ When including short term temporary load and short term effect of permanent load and long term temporary load: 1.00

+ When including repeated load as well as long term effect of permanent load and long term temporary load for structure from:

- Heavy concrete:

In natural moisture condition: 1.50

In water saturation state: 1.20

When water and dry saturation state change in shifts: 1.75

Small particle concrete, light concrete, porous concrete and cellular concrete: taken in equation (147);

η - taken in equation (147);

d_w – stirrup diameter;

$$\alpha = E_S / E_b \; ; \; \mu_w = A_{sw} / bs \, .$$

Stress on stirrup is specified by equation:

$$\sigma_{sw} = \frac{Q - Q_{b1}}{A_{sw} h_0} s \qquad (156)$$

But not greater than $R_{s,ser}$.

In equation (156):

Q and Q_{b1} – corresponding to left side and right side of condition (84) but replacing value R_{bt} with $R_{bt,ser}$,

With coefficient γ_{b4} multiplying with 0.8.

When there is no normal crack on considering shear forced zone, meaning that satisfying the item (127), the increase of shear force Q_{b1} born by member calculating form condition (144) should be mentioned.

Calculation strength $R_{bt,ser}$ and $R_{b,ser}$ is not greater than corresponding value of concrete grade B30.

Value a_{crc} calculated by equation (155) should be more increased 30% for member made from light concrete grade B7.5 and below.

When determining short term and long term oblique crack width, it should obey the instructions in subclause 7.2.2.1 on mentioning to long term effect of load.

7.3. Calculating on reinforced concrete member according to crack closing.

7.3.1. General principle

Reinforced concrete member should be calculated according to crack closing:

- Normal to longitudinal axis;

- Inclined with longitudinal axis.

7.3.2. Calculation according to crack closing normal to longitudinal axis

7.3.2.1. In order to ensure firmly close crack normal to longitudinal when bearing effects of long term temporary and permanent load, the following conditions should be obeyed:

a) In tension reinforcement S bearing permanent load, short term and long term temporary load, in order to avoid the appearance of non-recoverable deformation, the following condition should be met:

$$\sigma_{sp} + \sigma_s \leq 0.8 R_{s,ser} \qquad (157)$$

Where:

σ_s - stress increment value in tension reinforcement S due to effect of external force, determined by equations from (149) to (151).

b) Member section with crack on tension zone due to effect of permanent load, short term and long term temporary load should be often compressed by effect of permanent load, long term temporary load and normal compression stress σ_b at tensile edge caused by external force is not less than 0.5 MPa. Quantity σ_b is determined the same with elastic object effected by external force and pre-compression stress.

7.3.2.2. For member stage with initial crack on compression zone (see subclause 4.2.9), value σ_{sp} in equation (157) multiply with coefficient $(1-\lambda)$, when determining stress ,σ_b quantity P is multiplied with coefficient $1{,}1(1-\lambda)$, but not greater than 1.0, in which value λ is specified according to subclause

7.1.2.5.

7.3.3. Calculation according to crack closing inclined with longitudinal axis

In order to ensure firmly close crack with longitudinal axis, both main stresses in concrete, determined according to subclause 7.1.3.1 at convert section center point level when bearing effect of permanent load, long term temporary load, should be compression stress and their value is not less than 0.6MPa.

The above requirement is ensured by pre-stress transversal reinforcement (inclined reinforcement or stirrup).

7.4. Calculating member of reinforcement concrete structure according to deformation

7.4.1. General principle

7.4.1.1. Deformation (deflection, rotation angle) of member's reinforcement concrete structure should be calculated according to structural mechanics, in which flexure value in calculation is determined according to instructions in subclauses 7.4.1.2 and 7.4.3.

Reinforced concrete member deformation flexure value is calculated from their initial state, from precompression state when there is pre-stress.

Initial flexure of determined self -stress member includes content and position of longitudinal reinforcement towards concrete section and compression force value in front of concrete.

7.4.1.2. Flexure is determined as the following:

a) For member stages that crack normal to longitudinal axis do not take shape in their tension zone determined the same with elastic object.

b) For member stages that there are crack normal to longitudinal axis in their tension zone: determined as ratio between difference of average deformation of outer fiber at concrete's compression zone and average deformation of tensile longitudinal reinforcement, and working height of member section.

Members or member stages are considered no crack in tension zone if crack is not formed when bearing permanent load, long term and short term temporary load or if they close when bearing permanent and long term temporary load, in which calculated load with confident coefficient $\gamma_f = 1{,}0$.

7.4.2. Determining reinforced concrete member flexure on stage that has no crack in tension zone.

7.4.2.1. On stages that they do not form crack normal to longitudinal axis, full flexure value of bent, eccentric compression and eccentric tension member should be specified by equation:

$$\frac{1}{r} = \left(\frac{1}{r}\right)_1 + \left(\frac{1}{r}\right)_2 - \left(\frac{1}{r}\right)_3 - \left(\frac{1}{r}\right)_4 \qquad (158)$$

In which:

$\left(\frac{1}{r}\right)_1, \left(\frac{1}{r}\right)_2$ - flexure due to short term temporary load (determined by subclause 4.2.3) and due to permanent and long term temporary load (excluding pre-stress force P), respectively, is determined by equations:

$$\left.\begin{aligned} \left(\frac{1}{r}\right)_1 &= \frac{M}{\varphi_{b1} E_b I_{red}} \\ \left(\frac{1}{r}\right)_2 &= \frac{M \varphi_{b2}}{\varphi_{b1} E_b I_{red}} \end{aligned}\right\} \qquad (159)$$

Where:

M – moment due to corresponding external force (short term and long term) towards axis normal to effected plane of bent moment and cross center point of convert section;

φ_{b1} - coefficient considering effect of short term creep of concrete, is taken as the following:

+ For heavy concrete, small particle concrete, light concrete with solid fine aggregate and cellular concrete (for two-layer pre-stress member made from cellular concrete and heavy concrete): is taken 0.85;

+ For light concrete with soft fine aggregate and hollow concrete: is taken 0.7;

φ_{b2} - coefficient considering effect of long term creep of concrete on non-crack member deformation, is taken according to table 33;

$\left(\frac{1}{\mathrm{r}}\right)_3$ - flexure caused by hogging of member due to short term effect of pre-compression stress P, is specified by equation:

$$\left(\frac{1}{r}\right)_3 = \frac{P e_{0p}}{\varphi_{b1} E_b I_{red}} \qquad (160)$$

$\left(\frac{1}{r}\right)_4$ - flexure caused by hogging of member due to shrinkage and creep of concrete when bearing precompression stress, is specified by equation:

$$\left(\frac{1}{r}\right)_4 = \frac{\varepsilon_b - \varepsilon'_b}{h_0} \qquad (161)$$

Where:

ε_b, ε'_b- relative deformation of concrete caused by shrinkage and creep of concrete due to precompression stress and is determined correlatively at center point lever of tensile longitudinal reinforcement and outer compression concrete fiber according to equation (162):

$$\varepsilon_b = \frac{\sigma_{sb}}{E_s}; \quad \varepsilon'_b = \frac{\sigma'_{sb}}{E_s} \qquad (162)$$

Value σ_{sb} is taken as the total of pre-stress loss caused by shrinkage and creep of concrete determined by items 6, 8, 9 table 6 towards reinforcement at tension zone; σ'_{sb} is taken the same with tensile reinforcement at outer compression concrete fiber or one not at outer compression concrete fiber.

Then the total $\left(\frac{1}{r}\right)_3 + \left(\frac{1}{r}\right)_4$ should not be taken below $\frac{P e_{0p} \varphi_{b2}}{\varphi_{b1} E_b I_{red}}$. For unprestress member, flexure value $\left(\frac{1}{r}\right)_3$ and $\left(\frac{1}{r}\right)_4$ are allowed to taken zero.

7.4.2.2. When determining the curve of the component with initial crack in the compressive region (See 4.2.9), the values of $\left(\frac{1}{r}\right)_1$, $\left(\frac{1}{r}\right)_2$ and $\left(\frac{1}{r}\right)_3$ defined according to formula (159), (160 is increased 15%, the value of $\left(\frac{1}{r}\right)_4$ defined according to formula (161) is increased 25%.

7.4.2.3. At area forming normal crack in tension zone, but it is closed by considering load, flexures $\left(\frac{1}{r}\right)_1$, $\left(\frac{1}{r}\right)_2$ and $\left(\frac{1}{r}\right)_3$ in equation (158) is increased to 20%.

Table 33. Factor φ_{b2}, consideration of long term concrete creep effects on deformation of members without cracking

Long term effect of load	Factor φ_{b2}, for structures made of			
	Heavy concrete, light concrete, porous concrete, cellular concrete (for double layer prestressed structure made of cellular concrete and heavy concrete	Small particle concrete group		
		A	B	C
1. Short term effect	1.0	1.0	1.0	1.0
2. Long term effect when atmospheric moisture is:				
a) 40% ÷ 75%	2.0	2.6	3.0	2.0
b) < 40%	3.0	3.9	4.5	3.0

Note 1: Classification of small particle concrete into group given in 5.1.1.3.

Note 2: When concrete alternatively changes water-dry saturated condition, value φ_{b2} shall be multiplied by factor 1.2 if subjected to long term load effect.

Note 3: When atmospheric moisture is greater than 75% and concrete is under water saturated condition, the value φ_{b2} given in item 2a of table 33 shall be multiplied by factor 0.8.

7.4.3. Determination of reinforced concrete member curvature on cracked portion in tension zone

7.4.3.1. In area where taking shape crack perpendicular to member longitudinal axis in tension zone, the curvature of bending members, eccentric compression members as well as eccentric tension, having rectangular section, T section, I section (parallelepiped) with $e_{0,tot} \geq 0,8h_0$, must be defined by the following formula:

$$\frac{1}{r} = \frac{M}{h_0 z}\left[\frac{\psi_s}{E_s A_s} + \frac{\psi_b}{(\varphi_f + \xi) b h_0 E_b \nu}\right] - \frac{N_{tot}}{h_0}\frac{\psi_s}{E_s A_s} \qquad (163)$$

Where:

M- Moment for axis perpendicular to moment action plane and passing through S reinforcement section gravity center, due to all external forces placed at one side of considering section, and due to P prestress;

z - distance from S reinforcement section gravity center to point locating resultant of forces in tension zone above cracks determined by instructions given in clause 7.4.3.2;

ψ_s - Factor taking into account concrete working in tension zone above cracking portion, determined by clause 7.4.3.3;

ψ_b: Factor taking into account deformation irregular distribution of extreme concrete fiber on the cracking portion length, and is determined as:

+ For heavy concrete, small particle concrete, light concrete with class higher than B 7.5: 0.9

+ For light concrete, porous concrete and cellular concrete with class equal to or lower than B 7.5: 0.7

+ For structure subjected to repeated load, not depending on concrete type and class 1.0

φ_f : factor, defined by the formula (167);

ξ : Relative height of compressed concrete zone, taken from 7.4.3.2;

ν : Factor characterizing concrete elastic -plastic state of the concrete at compression zone, taken from Table 34;

N_{tot} : Resultant of longitudinal force N and prestress P (with eccentric tension, force N taken with "minus" mark).

For member without strain reinforcement, it allows to take P force equal to zero.

When determining member curvature above initial cracking portion in compression zone (see clause 4.2.9), P value is reduced by a quantity ΔP , calculated by formula (153).

For eccentric bending and compression members made of heavy concrete, when $M_{crc} < M_{r2} <$ $< \left(M_{crc} + \psi bh^2 R_{bt,ser}\right)$, curvature due to moment M_{r2} should be defined by linear interpolate between values:

- Curvature due to moment M_{crc} is determined as for continuously elastic object as given in clauses 7.4.2.1, 7.4.2.2, 7.4.2.3.

- Curvature due to moment $\left(M_{crc} + \psi bh^2 R_{bt,ser}\right)$ is determined by instructions in this clause. ψ. factor is determined by instructions given in 7.2.2.1b and reduced by 2 times if calculating the long term effect of permanent load and long term temporary load.

Table 34: ν factor characterizing elastic-plastic condition compressed concrete zone

Long term effect of load	Factor ν, for members made from					
	heavy concrete, light concrete	Porous concrete	Small particle concrete group			Cellular concrete
			A	B	C	
1. Short term effect	0.45	0.45	0.45	0.45	0.45	0.45
2. Long term effect when atmospheric moisture is:						
a) 40%-75%	0.15	0.07	0.1	0.08	0.15	0.2
b) < 40%	0.1	0.04	0.07	0.05	0.1	0.1

***Note** 1: Types of small particle concrete given in 5.1.1.3;*

***Note** 2: When concrete changes water-dry saturated condition, value ν shall be multiplied by 1.2 factor if load bearing in long term.*

***Note** 3. When atmospheric moisture is greater than 75% and concrete is under water saturated condition, the value ν given in item 2a of this table shall be divided by 0.8 factor.*

7.4.3.2. Value ξ shall be calculated by the formula:

$$\xi = \frac{1}{\beta + \dfrac{1 + 5(\delta + \lambda)}{10\mu\alpha}} \pm \frac{1,5 + \varphi_f}{11,5\dfrac{e_{s,tot}}{h_0} \mp 5} \qquad (164)$$

But can not be greater than 1.0

The second term of the right side of formula (164) shall be taken "plus" sign when the force N_{tot} is compression and "minus" sign when the force N_{tot} is tension (see 7.4.3.1).

In formula (164):

β - factor, taken as follows:

+ for heavy concrete and light concrete: 1.8

+ for small particle concrete: 1.6

+ for hollow concrete and cellular concrete: 1.4

$$\delta = \frac{M}{bh_0^2 R_{b,ser}} \qquad (165)$$

$$\lambda = \varphi_f \left(1 - \frac{h_f^{'}}{2h_0}\right) \qquad (166)$$

$$\varphi_f = \frac{\left(b_f^{'} - b\right)h_f^{'} + \frac{\alpha}{2\nu}A_s^{'}}{bh_0} \qquad (167)$$

$e_{s,tot}$ - eccentricity of N_{tot} force towards gravity center of S reinforcement section, corresponding to moment M (see clause 7.4.3.1), is defined by the formula:

$$e_{s,tot} = \left|\frac{M}{N_{tot}}\right| \qquad (168)$$

Value z is defined by the formula:

$$z = h_0\left[1 - \frac{\frac{h_f^{'}}{h_0}\varphi_f + \xi^2}{2\left(\varphi_f + \xi\right)}\right] \qquad (169)$$

- For eccentric compression member, value z shall not be greater than 0.97 $e_{s,tot}$;

- For rectangular section member or T flanged section member in tension zone, in formula (166) and (169), replace h'_f by $2a'$ or $h'_f = 0$ with or without S' reinforcement f h = 0 respectively;

- Flanged sections in compression zone, when $\xi < h'_f / h_o$ shall be calculated as rectangular section with width of b'_f.

- Design width of b'_f flange shall be defined by instructions in clause 6.2.2.7.

7.4.3.3. Factor ψ_s for member made of heavy concrete, small particle concrete, light concrete and prestressed double- layer structure made of cellular concrete and heavy concrete shall be defined by the formula:

$$\psi_s = 1.25 - \varphi_{ls}\,\varphi_m - \frac{1 - \varphi_m^2}{\left(3.5 - 1.8\varphi_m\right)e_{s,tot}/h_0} \qquad (170)$$

but not greater than 1.0 where $e_{s,tot}/h_0 \geq 1,2/\varphi_{ls}$

For unprestressed bending member, the last term of the right side of formula (170) is allowed to take equal to zero.

In the formula (170):

φ_{ls} - factor taking into account long term load effect, given in table 35;

$e_{s,tot}$ - see formula (168);

$$\varphi_m = \frac{R_{bt,ser} W_{pl}}{\left| \pm M_r \mp M_{rp} \right|} \qquad (171)$$

but not greater than 1.0;

Where:

W_{pl} - see formula (141);

M_r, M_{rp} - see clause 7.1.2.4 in which moment is considered positive if causing S reinforcement tension.

Table 35: Factor φ_{ls}

Long term effect of load	Factor φ_{ls} corresponds to concrete class	
	> B7.5	≤ B7.5
1. Short term effect, when reinforcement is:		
a) Steel bar with		
- plain shape	1.0	0.7
- flanged shape	1.1	0.8
b) Steel wire	1.0	0.7
2. Long term effect (not depend on reinforcement types)	0.8	0.6

For single-layer structure made of cellular concrete (unprestressed), value ψ_s is calculated by the formula:

$$\psi_s = 0,5 + \varphi_l \frac{M}{M_{ser}} \qquad (172)$$

Where:

M_{ser}: Bending strength of member section according to strength calculation with concrete and reinforcement design intensity calculated by second limit states.

φ_l : Factor, taken as follows:

with short term load effect for flanged reinforcement: 0.6

with short term load effect for plain reinforcement: 0.7

with long term load effect does, not depending on steel bar section shape: 0.8

For fatigue bearing structure, value ψ_s is equal to 1.0 in all cases.

7.4.3.4. The overall curvature $\frac{1}{r}$ for cracking portion in tension zone shall be defined by the formula:

$$\frac{1}{r} = \left(\frac{1}{r}\right)_1 - \left(\frac{1}{r}\right)_2 + \left(\frac{1}{r}\right)_3 - \left(\frac{1}{r}\right)_4 \qquad (173)$$

In which:

$\left(\frac{1}{r}\right)_1$ - curvature due to short term effect of overall load used for deformation calculation as instructed in clause 4.2.11;

$\left(\frac{1}{r}\right)_2$ - curvature due to short term effect of permanent load and long term temporary load;

$\left(\frac{1}{r}\right)_3$ - curvature due to long term effect of permanent load and long term temporary load;

$\left(\frac{1}{r}\right)_4$ - camber due to concrete shrinkage and creep when bearing P prestress, shall be defined by the formula (161) and instructions given in clause 7.4.2.2.

Curvatures $\left(\frac{1}{r}\right)_1$, $\left(\frac{1}{r}\right)_2$ and $\left(\frac{1}{r}\right)_3$ shall be defined by the formula (163) where $\left(\frac{1}{r}\right)_1$ and $\left(\frac{1}{r}\right)_2$ are calculated with value ψ_s and ν corresponding to short term load effect, $\left(\frac{1}{r}\right)_3$ is calculated with value ψ_s and ν corresponding to long term load effect. If the values $\left(\frac{1}{r}\right)_2$ and $\left(\frac{1}{r}\right)_3$ are negative, they are taken equal to 0.

7.4.4. Calculation of deflection

7.4.4.1. Deflection f_m due to bending deformation shall be calculated as follows:

$$f_m = \int_0^l \overline{M}_x \left(\frac{1}{r}\right)_x dx \qquad (174)$$

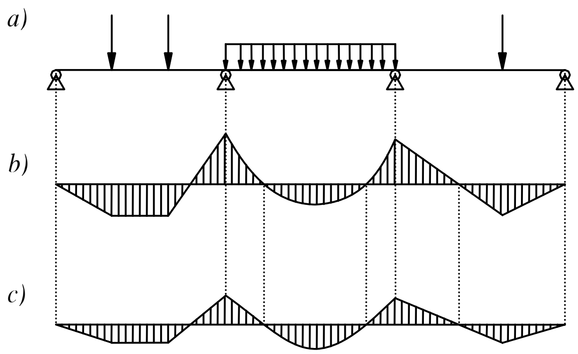
In which:

$\overline{M}_x$ - bending moment at section x due to effect of unit force placed in displacement direction determined of member at section x along the span with curvature to be defined.

$\left(\frac{1}{r}\right)_x$ - the entire curvature at section x due to load causing deflection determined; value $\frac{1}{r}$ shall be defined by formula (158), (173) respectively to portions with and without cracks; mark of $\frac{1}{r}$ shall be taken in accordance with deflection diagram.

For bending member (without prestressed reinforcement) with constant section, with cracks, on each bending moment portion of unchangeable mark, it allows to calculate curvature for maximum stress section, curvature of all rest sections in this portion shall be taken in proportion with bending moment value (Figure 23).

7.4.4.2. For bending member when $l/h < 10$, shear force effect on deflection is necessary to taken into account. In this case, overall deflection f_{tot} is the sum of bending deflection f_m and deflection due to shearing deformation f_q.



a- load outline; b - bending moment outline; c - curvature outline

Figure 23: *Diagram of bending moment and curvature for constant section reinforced concrete member*

7.4.4.3. Deflection f_q due to shearing deformation shall be calculated by the formula:

$$f_q = \int_0^l \overline{Q}_x \gamma_x \, dx \qquad (175)$$

In which:

$\overline{Q}_x$ - Shear force in section x due to unit load acting in displacement direction is determined and placed at section which is necessary to determine deflection;

γ_x : Shearing deformation, determined by the formula:

$$\gamma_x = \frac{1.5 Q_x \varphi_{b2}}{G b h_0} \varphi_{crc} \qquad (176)$$

In which:

Q_x : Shear force at section x due to external force effect;

G : Sliding modulus of concrete;

φ_{b2} : Factor taking into account long term effect of concrete, given in table 33;

φ_{crc} : Factor taking into account cracking effect on shearing deformation, calculated as follows:

+ On portions along with member length which do not have cracks normal and diagonal to member longitudinal axis: 1.0;

+ On portions having only cracks diagonal to member longitudinal axis: 4.8;

+ On portions having only cracks normal to, or cracks normal to and at the same time diagonal to member longitudinal axis, shall be determined by the formula:

$$\varphi_{crc} = \frac{3 E_b I_{red}}{M_x}\left(\frac{1}{r}\right)_x \qquad (177)$$

Where M_x, $\left(\frac{1}{r}\right)_x$ - external force moment and overall curvature at section x due to load causing deflection, respectively.

7.4.4.4. For reinforced slab with thickness less than 25 cm (not including slabs placing at 4 sides) placed with plane steel meshes, cracks in tension zone, the deflection value calculated according to formula (174) shall be multiplied with factor $\left(\frac{h_0}{h_0 - 0,7}\right)^3$, but should not be taken greater than 1.5 (h_0 in cm).

7.4.4.5. When calculating member placed with one reinforcement layer (Figure 24) by finite element method (or other mathematic methods), it is allowed to replace the equation (163) by set of symmetrically physic equations as follows:

$$\left.\begin{aligned} \frac{1}{r} &= B_{11}\, M + B_{12}\, N \\ \varepsilon_0 &= B_{12}\, M + B_{22}\, N \end{aligned}\right\} \qquad (178)$$

In which:

$$M = M_{act} \mp P e_{0p} \qquad (179)$$

$$N = \mp N_{act} - P \qquad (180)$$

$$B_{11} = \frac{1}{(z_s + z_b)^2}\left[\frac{\psi_b}{(\varphi_f + \xi) b h_0 E_b \tilde{\nu}} + \frac{\psi_s}{E_s A_s}\right] \qquad (181)$$

$$B_{12} = \frac{1}{(z_s + z_b)^2}\left[\frac{\psi_s z_b}{E_s A_s} - \frac{\psi_b z_s}{(\varphi_f + \xi) b h_0 E_b \tilde{\nu}}\right] \qquad (182)$$

$$B_{22} = \frac{1}{(z_s + z_b)^2}\left[\frac{\psi_b z_s^2}{(\varphi_f + \xi) b h_0 E_b \tilde{\nu}} + \frac{\psi_s z_b^2}{E_s A_s}\right] \quad (183)$$

$$\tilde{\nu} = 2\nu \quad (184)$$

ε_0 - elongation or shrinkage along with y axis;

M_{act} - moment due to external force placed at one side of considering section for y axis;

N_{act} - longitudinal force placed at y axis level, taken "plus" sign when causing tension;

z_s, z_b - respectively are distance from y axis to a point placing force resultant of tensile reinforcement and to force resultant in compressed concrete;

ξ : determined by clause 7.4.3.2;

ν : Factor, given in table 34;

φ_f : Factor, determined by the formula (167), not taking into account reinforcement placed in sectional tension zone.

ψ_s : Determined as given in 7.4.3.3.

ψ_b : Determined as given in 7.4.3.1.

Y axis is placed within the working height of section in order to simplify calculation scheme. If y axis is placed higher than section gravity center of compression zone, z_b value must be taken with negative mark.

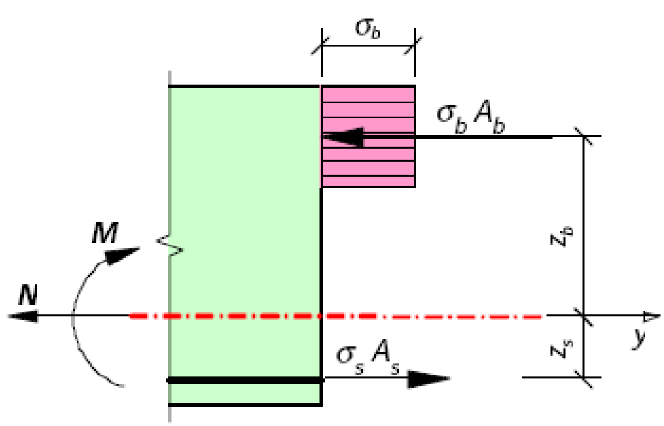


Figure 24: Internal force diagram and stress graph on section normal to member longitudinal axis, having one reinforcement layer with deformation calculation.

For the second term in the formula (179), "negative" sign shall be taken if P force is placed below y axis; if P force is placed higher than y axis, taking "positive" sign.

For the first term in the formula (180), "positive" sign shall be taken if N_{act} force is tensile, "negative" sign if N_{act} force is compressive.

7.4.4.6. When calculating member having multilayer reinforcement (Figure 25), use set of general physic equations as follows:

$$\left.\begin{aligned} M &= D_{11}\frac{1}{r} + D_{12}\,\varepsilon_0 \\ N &= D_{12}\frac{1}{r} + D_{22}\,\varepsilon_0 \end{aligned}\right\} \qquad (185)$$

In which:

$$D_{11} = \sum_{i=1}^{n}\frac{E_{si}}{\psi_{si}}A_{si}\,z_{si}^2 + \sum_{j=1}^{k}E_{sj}\,A'_{sj}\,z_{sj}^2 + \left(\varphi_f + \xi_1\right)\frac{bh_0\,E_b\,\tilde{v}}{\psi_b}z_b^2 \qquad (186)$$

$$D_{12} = \sum_{i=1}^{n}\frac{E_{si}}{\psi_{si}}A_{si}\,z_{si} + \sum_{j=1}^{k}E_{sj}\,A'_{sj}\,z_{sj} + \left(\varphi_f + \xi_1\right)\frac{bh_0\,E_b\,\tilde{v}}{\psi_b}z_b \qquad (187)$$

$$D_{22} = \sum_{i=1}^{n}\frac{E_{si}}{\psi_{si}}A_{si} + \sum_{j=1}^{k}E_{sj}\,A'_{sj} + \left(\varphi_f + \xi_1\right)\frac{bh_0\,E_b\,\tilde{v}}{\psi_b} \qquad (188)$$

In which:

i - number of tensile longitudinal reinforcement bar;

j - number of compressive longitudinal reinforcement bar;

ξ_1 - relative height of compressive zone of the section: $\xi_1 = \frac{x}{h_{01}}$

φ_f : determined by formula (167) not taking into account S' reinforcement;

z_{si} , z_{sj} - distance from i^{th} reinforcement gravity center and j^{th} reinforcement gravity center to y axis.

In formula (187), values z_{si} , z_{sj} , z_b shall be taken with "positive" sign if placed below y axis; vice versa with "negative" sign.

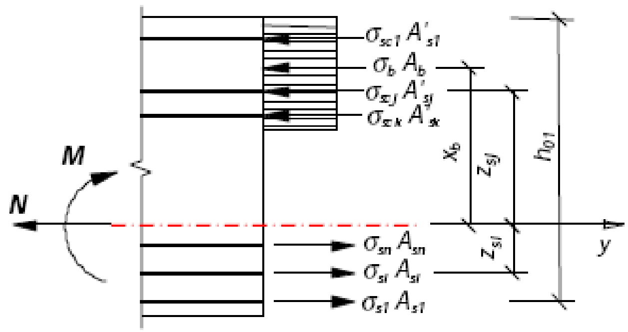


Figure 25: Internal force diagram and stress graph on section normal to member longitudinal axis, having multi-layer reinforcement with deformation calculation.

Values ξ_1 and ψ_{si} in equations from (186) to (188) are allowed to be determined as stipulated in subclause 7.4.3.2 and 7.4.3.3, but in calculation formulas, replacing h_0 by h_{01}, A_s by $\sum A_{si} \frac{h_{0i} - 1,3x}{h_{01} - 1,3x}$ (when determining μ) and φ_m by $\varphi_{m1} = \varphi_m (h_{01}/h_{0i})$.

8. Structure requirements

8.1. General requirements

When designing concrete and reinforced concrete structure, in order to ensure conditions on manufacture, life and simultaneous working of concrete and reinforcement, it needs to satisfy structure requirements given in this part.

8.2. Minimal dimension of member section

8.2.1 . Minimum dimensions of concrete and reinforced concrete member sections that are determined from calculations according to acting internal force and respective limit condition groups, shall be chosen while taking into account economic requirements, necessity of formwork and reinforcement layout unification, as well as conditions on member manufacture technological conditions.

Furthermore, dimensions of reinforced concrete member section shall be chosen so as to ensure requirements on reinforcement layout in section (protective concrete layer thickness, distance between reinforcement bars, etc...) and reinforcement anchor.

8.2.2. Thickness of monolithic plate shall be not smaller than:

- For roof floor:...40mm
- For house and public work floors:...50mm
- For manufacturer's floor between stories:...60mm

- For plate made of light concrete of class B7.5 and lower class:..70mm

Minimal thickness of mounted plated shall be determined from conditions ensuring required thickness of protective concrete layer and conditions for reinforcement layout on plate thickness (see clause 8.3.1. to clause 8.4.2).

Sectional dimensions of eccentric compression member shall be chosen so that the slenderness l0/i in any direction does not exceed:

- For concrete reinforcement member made of heavy concrete, small particle concrete, light concrete:..200

- For house column: 120

- For concrete member made of heavy concrete, small particle concrete, light concrete, porous concrete :...90

- For concrete and reinforcement concrete members made of cellular concrete:...............................70

8.3. Protective concrete layer

8.3.1. Protective concrete layer of loaded reinforcement should ensure simultaneous working of reinforcement and concrete during all structure working stages, as well as protect reinforcement from atmosphere, temperature effects and similar effects.

8.3.2. For loaded longitudinal reinforcement (unprestressed, prestressed, base tensile prestressed), protective concrete layer thickness shall be taken not smaller than reinforcement and cable diameter and not less than:

- For plate and wall having thickness of:

+ 100 mm and below:.. 10 mm (15 mm)

+ more than 100 mm: ....15 mm (20 mm)

- For beam and lateral beam having height of:

+ less than 250 mm: ....15 mm (20 mm)

+ more than or equal to 250 mm:..20 mm (25 mm)

- Inside of column: ....20 mm (25 mm)

- Inside of foundation beam: ....30 mm

- Inside of foundation:

+ mounted:..30 mm

+ monolithic with lining concrete layer: ....35 mm

+ monolithic without lining concrete layer: ....70 mm

Note 1: Values given between brackets shall be used for outdoor structures or humid areas.

Note 2: For structures in area influenced by marine environment, protective concrete layer thickness shall be determined by requirements given in effective standard TCVN 9346 : 2012.

In monolayer structure made of light concrete and porous concrete of class B7.5 and lower, protective concrete layer thickness shall not be smaller than 20 mm, and not smaller than 25 mm for exterior wall panels (without coat).

For monolayer structures made of cellular concrete, protective concrete layer shall not be smaller than 25 mm in all cases.

For areas influenced by brine vapor, protective concrete layer shall be determined by requirements given in effective standards.

8.3.3. Thickness of protective concrete layer for stirrup, distributing reinforcement and secondary reinforcement shall not be smaller than these reinforcement diameter and not smaller than:

- when member section height is lower than 250 mm: ....10 mm (15 mm).

- when member section height is equal to and greater than 250 mm: ....15 mm (20 mm).

Note 1: Values given between brackets shall be used for outdoor structures or humid areas.

Note 2: For structures in area influenced by marine environment, protective concrete layer thickness shall be determined by requirements given in effective standard TCVN 9346 : 2012.

For members made of light concrete, porous concrete of class lower than B7.5 and cellular concrete, thickness of protective concrete layer for transverse reinforcement shall be not less than 15 mm, in despite of section height.

8.3.4. Thickness of protective concrete layer at the ends of prestressed member longitudinal to stress transmitting portion length (see clause 5.2.2.5) shall be not smaller than:

- For steel bar of classes CIV, A-IV, A-IIIB:...2d

- For steel bar of classes A-V, A-VI, AT-VII:...3d

- For cable reinforcement:...2d

(d is here in mm).

Furthermore, protective concrete layer thickness of these above mentioned zones must be not smaller than 40 mm for all bar reinforcements and 30 mm for cable reinforcements.

It allows concrete layer protecting prestressed reinforcement with anchor or without anchor at bearing section to be taken as at span section in the following cases:

a) For prestressed members having concentrative transmitting bearing forces, when having steel bearing details and indirect reinforcement (transverse reinforcement made of welded steel wire or stirrup surrounding longitudinal reinforcement), locate as instructions given in 8.12.9.

b) In plates, panels, slabs and column foundation of power line when adding supplement transverse reinforcement at the member ends (steel mesh, enclosed stirrup) as given in clause 8.12.9.

8.3.5. In members having prestressed longitudinal reinforcement tensioned on concrete and placed between steel ducts, distance from member surface to duct surface shall be not less than 40 mm and not smaller than steel duct width. Besides, this above distance to member lateral side shall be not less than 1/2 of steel duct height.

When laying prestressed reinforcement in open slot or outside of section, protective concrete layer thickness formed after that by cement injection method or other methods shall be not less than 30 mm.

8.3.6. In order to ensure intact layout of reinforcement bar, steel wire or steel frame into formwork longitudinal to whole member length (or width), these reinforcement ends shall be placed apart from member edge by a distance of:

- For member of dimensions below 9 m:...10 mm
- For member of dimensions below 12 m:...15 mm
- For member of dimensions above 12 m: ....20 mm

8.3.7. In members having ear-ring section or box section, distance from longitudinal reinforcement bar to member inside face must meet requirements given in 8.3.2 and 8.3.3.

8.4. Minimum distance between reinforcement bars

8.4.1. Clearance distance between reinforcement bars (or prestressed reinforcement duct casing) according to section height and width should ensure simultaneous working of reinforcement with concrete and be chosen in taking into account facility of concrete placement and compaction. For prestressed structures, it is necessary to consider concrete local compression and pulling device dimensions (jack, clamp). For members using platform vibrator or needle vibrator, manufacture must be taken into account distance between reinforcement bars so that vibrator can pass through for compacting concrete.

8.4.2. Clearance distance between non-prestressed or prestressed longitudinal reinforcement bars tensioned on the base, as well as distance between adjacent welded steel frame bars, shall be not less than greatest bar diameter and not less than the regulated values as follows:

a) When placing concrete, reinforcement bars are in transverse or diagonal position: be not less than: 25 mm for under reinforcement and 30 mm for upper reinforcement. When under reinforcements are set more than two layers by height, distance between bars in transverse direction (excluding those in two lowest layers) shall be not less than 50 mm.

b) When placing concrete, reinforcement bars are in vertical position: be not less than 50 mm. When systematically controlling concrete aggregate dimensions, this distance can be reduced to 35 mm but not 1.5 times less than biggest coarse aggregate dimension.

In the narrow, it allows to lay reinforcement bars by couple (without slit between them).

For members having prestressed reinforcement tensioned on concrete (excluding structures placed with continuous reinforcement), clearance distance between steel ducts must be not less than duct diameter and 50 mm in all cases.

Note: Clearance distance between flanged reinforcement bars should be taken according to nominal diameter excluded flanges.

8.5. Anchorage of unprestressed reinforcement

8.5.1. For flanged reinforcement bars as well as round plain bars used for welded steel frame and welded mesh, their ends should be let straight, not need to be hook. Tensile round plain reinforcement bars in frame and bound mesh shall be hook at the end by L or U shape.

8.5.2. Tensile longitudinal reinforcement bars and compressive reinforcement must be lengthened over section perpendicular to member longitudinal axis where they are calculated with whole design intensity; by a distance not less than l_{an} determined by the formula:

$$l_{an} = \left(\omega_{an} \frac{R_s}{R_b} + \Delta\lambda_{an} \right) d \qquad (189)$$

But not less than $l_{an} = \lambda_{an} d$

Where ω_{an}, $\Delta\lambda_{an}$ and λ_{an} values as well as permitted minimum value l_{an} shall be taken from table 36.

As the same time, round plain reinforcement bars should be hook at the end or welded with stirrup along anchor length. It allows to calculate R_b in taking into account factors for concrete working condition, except factor γ_{b2}.

For members made of Group B small particle concrete, length l_{an} according to formula (189) shall be increased by 10d for tensile reinforcement and 5d for compressive reinforcement.

When bars subjected to anchorage have sectional area greater than required area according to strength calculation with whole design intensity, length l_{an} given in formula (189) is allowed to be reduced by multiplying with necessary calculated area ratio and real area of reinforcement section.

If according to design, cracks are formed along bars subjected to anchorage due to tensile concrete, these bars shall be lengthened over compression zone by a distance of l_{an} given in formula (189).

When these requirements can not be met, it needs to have method for anchoring longitudinal reinforcement bars so that they can work with whole design intensity at considering section (setting indirect reinforcement, welding bar tip to anchorage plate or preset details, bending anchoring bar), so length l_{an} shall be not less than 10d.

Preset details shall be considered in following characteristics: length of tensile anchoring bars of preset details fixed in tensile or compressed concrete zone when $\sigma_{bc}/R_b > 0.75$ or $\sigma_{bc}/R_b < 0.25$ shall be determined by formula (189) with ω_{an}, $\Delta\lambda_{an}$ and λ_{an} values taken from section 1b of table 36. Where

σ_{bc} is compressive stress in concrete acting perpendicularly to anchoring bar, which shall be determined as elastic materials on converting section permanently load bearing with load confidence factor $\gamma_f = 1$.

When preset detail anchoring bar is subject to tension and shear forces, second member of formula (189) shall be multiplied with factor δ determined by the formula:

$$\delta = \frac{0.3}{1 + Q_{an1}/N_{an1}} + 0.7 \qquad (190)$$

Where:

N_{an1}, Q_{an1} - are tension force and shear force in anchoring bar, respectively.

At the same time, anchoring bar length shall be not smaller than minimum value l_{an} specified in this clause.

Anchor made of round plain steel of CI , A-I groups could be used only when having reinforcement at bar ends by steel plates, filling out bar ends or welding short portions across bars. Length of these bars shall be designed for pulling out resistance and concrete partial compression. It allows to use anchor made of above mentioned steel with hook at its end for structural details.

8.5.3. In odder to ensure anchorage of longitudinal reinforcement strained to bearing edge, at extreme free bearings of bending members, it requires that:

a) If condition 6.2.3.4 is satisfied, length of tensile reinforcement bar strained to free bearing shall be not less than 5d.

b) If condition 6.2.2. 4 can not be met, length of tensile reinforcement bar strained to free bearing shall be not less than 10d.

Table 36: Factor for determining unprestressed reinforcement anchoring portions

Working conditions of unprestressed reinforcement	Factor for determining unprestressed reinforcement anchoring portion							
	Flanged reinforcement				Plain reinforcement			
	ω_{an}	$\Delta\lambda_{an}$	λ_{an}	l_{an}, mm	ω_{an}	$\Delta\lambda_{an}$	λ_{an}	l_{an}, mm
			Not less than				Not less than	
1. Reinforcement anchoring portion								
a. Tensile in tensile concrete	0.7	11	20	250	1.2	11	20	250
b. Compressive or tensile in compressed concrete zone.	0.5	8	12	200	0.8	8	15	200
2. Overlapping reinforcement								
a. In tensile concrete	0.9	11	20	250	1,55	11	20	250
b. In compressive concrete	0.65	8	15	200	1	8	15	200

Length of anchor portion l_{an} at extreme free bearing where reinforcement design intensity are reduced (see clause 5.2.2.4 and table 23), can be determined by instructions given in 8.5.2 and section 1b of table 36.

When having indirect reinforcement, length of anchor portion can be decreased by dividing factor ω_{an} by quantity $1+12\mu_v$ and reducing factor an $\Delta\lambda_{an}$ by $10\sigma_b / R_b$.

Where:

μ_v - reinforcement content according to volume, determined by:

+ for welded steel mesh, using formula (49), see clause 6.2.2.13;

+ folded stirrup, using formula: $\mu_v = \dfrac{A_{sw}}{2as}$

Where:

A_{sw} - sectional area of folded stirrup placed along member edge.

μ_v value shall not be greater than 0.06 in all cases.

Concrete compressive stress on bearing σ_b shall be determined by dividing bearing reaction by bearing area of member and shall be not greater than 0.5 Rb.

Indirect reinforcement shall be distributed on anchor portion, from member tips to normal crack nearest to bearing.

Length of anchor portion strained to bearing can be reduced in comparison with required length stipulated in this clause if value l_{an} < 10d and could be equal to l_{an} but not less than 5d. In this case as well as for case where bar ends are firmly welded to steel preset details, longitudinal reinforcement design intensity at bearing do not need to be reduced.

8.6. Longitudinal reinforcement layout for members

8.6.1. Sectional area of longitudinal reinforcement in reinforced concrete member shall not be smaller than values given in table 37.

Table 37 – Minimum section area of longitudinal reinforcement in reinforced concrete member, % concrete section area

Working condition of reinforcement	Minimum section area of longitudinal reinforcement in reinforced concrete member, % concrete section area
1. Reinforcement S in bent moment member, eccentric tensile member when longitudinal force outer working height limit of section.	0.05
2. Reinforcements S, S' in eccentric tensile member when longitudinal force is between reinforcements S and S'	0.06
3. Reinforcements S, S' in eccentric tensile member when:	
$l_0 / i < 17$	0.05
$17 \leq l_0 / i \leq 35$	0.10
$35 < l_0 / i \leq 83$	0.20
$l_0 / i > 83$	0.25
Note: Minimum reinforcement section area in this table is for concrete section area calculated by multiplying the rectangle section width or T(or I) section web width with the working height of section h_0. In members with longitudinal reinforcement arranged regularly section perimeter as well as in centric tensile members the above minimum reinforcement value is for area of total concrete sections.	

In members with longitudinal reinforcement arranged regularly according to section perimeter as hooked transversal reinforcement bars as in centric tensile members, minimum reinforced section area of total longitudinal reinforcements is taken double the value in Table 37.

Minimum content of reinforcements S and S' in eccentric compression members that their force ability corresponding to eccentric calculation is used not over 50% shall be taken 0.05 not depending on member slenderness.

Regulations in Table 37 shall not be applied in choosing reinforcement section area when calculate member in manufacturing and transporting process ; in this case reinforcement section area is determining by strength analysis. If force ability of member is lost at the same time with crack forming in concrete tension zone, requirements in clause **4.2.10** for few reinforcement member should be considered.

No need to consider regulations in this clause when specify reinforcement area arranged according to perimeter of plate or panel corresponding to bending calculations in plate plane (panel).

8.6.2. Longitudinal reinforcement diameter of compression member is not allowed over value:

- For heavy concrete, small particle concrete with grade below B25: ... 40 mm

- For light concrete, hollow concrete with grade:

+ below B12.5 .... 16 mm

+ B15 – B25: .... 25 mm

+ over B30 .... 40 mm

- For cellular concrete with grade

+ below B10 .... 16 mm

+ B12.5 – B15: .... 20 mm

In bent member made from light concrete using reinforcement group CIV, A-IV and lower, longitudinal reinforcement diameter is not greater than:

- For concrete grade from B12,5 and below:.. 16 mm

- For concrete grade B15 – B25: .... 25 mm

- For concrete grade over B30:... 32 mm

For reinforcement grade greater, limit diameter of reinforcement bar should be appropriate with current regulations.

In bent moment made from cellular concrete with grade B10 and lower, longitudinal reinforcement diameter is not greater than 16 mm.

Longitudinal reinforcement diameter in eccentric compression member of total block placing structure is not less than 12 mm.

8.6.3. In eccentric compression straight member, space between axes of longitudinal reinforcement bar in direction normal to bent plane is not greater than 400 mm, in direction of bent plane – is not greater than 500 mm.

8.6.4. In eccentric compression member that their force ability according to predicted eccentricity of longitudinal force is less than 50%, as well as in structure with slenderness l_0 / i<17 (e.g.: short column) not requiring compression reinforcement in design, and amount tensile steel is not over 0,3% allow not placing longitudinal and transversal reinforcement (according to regulation in clauses **8.6.3, 8.7.1, 8.7.2**) on sides parallel with bent plane. Then, on sides normal to bent plane with welding steel frame, steel grid with protection concrete layer is not less than 50 mm and not less than double longitudinal reinforcement diameter.

8.6.5. In beam with the width over 150 mm, the number of bearing longitudinal reinforcement pulled into support not less than two bars. In flank of joining panels and in beam with width equal or below 150 mm allow pulling a bearing longitudinal reinforcement bar into support.

Space between reinforcement bars pulled into support is not over 400 mm in floor slab, section area of these reinforcement bars are not less than 1/3 section area of reinforcement bars in span determined by maximum bent moment at the same time.

In prestress plates with porous hole (round porous hole) made from heavy concrete, and the height less than 300 mm, space between tensile reinforcements inserting into support is increased to 600 mm, if on section normal to plate longitudinal axis crack moment value M_{crc} in equation (128) is not less than 80% moment value due to external force calculated with load confidence factor $\gamma_f = 1$.

When placing reinforcement for continuous plate by roll welded fabric, allow bending all reinforcement bars below fabric to upper in segment near intermediate support.

Space between axes of bearing reinforcement bars in the middle of span and above bearing support (top bar) is not greater than 200 mm if the thickness of plate is less than or equal to 150 mm and not greater than 1.5 h if the thickness of plate is greater than 150 mm, where h is the thickness of plate.

8.6.6. In bent member with the height of section is greater than 700 mm, at sides should place structural longitudinal reinforcements providing that space between them according to the height is not greater than 400 mm and section area is not less than 0,1% concrete section area with dimension:

- according to the height of member: equal to space between these reinforcement bars;

- according to the width of member: equal to 1/2 the width of beam or flank, but not greater than 200 mm.

8.7. Arrange transversal reinforcement for member

8.7.1. At all member sides with longitudinal reinforcement, should arrange stirrup around extreme longitudinal reinforcement bars, space between stirrup bars at each sides of member should be not greater than 600 mm and not greater than double the width of member at the same time.

In eccentric compression member with tensile longitudinal reinforcement in the middle of the section (e.g.: prestress pile), stirrup might not be placed if concrete itself strong enough to bear transversal force.

In bent member, if according to the width of thin flank (flank width is equal to or less than 150 mm) there is only a longitudinal reinforcement bar or a welding steel frame, stirrup shall be not placed according to the width of that flank.

In eccentric compression straight, as well as in compression zone of bent moment with longitudinal reinforcement compressed by design, stirrup should be arranged with space as the following:

- In member made from heavy concrete, small particle concrete, light concrete, porous concrete:

+ When $R_{sc} \leq 400$: not greater than 500 mm and not greater than:

15d for fastening steel frame;

20d for welding steel frame;

+ When $R_{sc} \geq 450$: not greater than 400 mm and not greater than:

12d for fastening steel frame;

15d for welding steel frame;

– In member made from cellular concrete with welding steel frame: not greater than 500 mm and not greater than 40d (where d – minimum diameter of compression longitudinal reinforcement, mm).

In such members, stirrup should be combined tightly with compression reinforcement bars so that these reinforcement bars are not swelled out in any directions.

At position that reinforcement bears non-welded accumulating connection force, space between stirrups of eccentric compression member is not greater than 10d.

If compression longitudinal reinforcement content S' is greater than 1.5%, as well as if total member section is compressed and total content of reinforcements S and S' are greater than 3%, spaces among stirrups are not greater than 10d and not greater than 300 mm.

Requirements of this items shall not be applied for longitudinal reinforcements arranged according to design, if the diameters of these reinforcements are not over 12 mm and less than 1/2 the thickness of protecting concrete layer.

8.7.2. In eccentric compression member, should design stirrup in fastening steel frame so that longitudinal reinforcements (be separated minimum by 1 bar) are placed at bent position of stirrup and these positions are far from each other not greater than 400 mm according to section side. When the width of section side is not greater than 400 mm and there are not greater than 4 longitudinal reinforcement bars on each sides, allow using one stirrup around total longitudinal reinforcement.

When compression members are structured by plane welding steel frames they should be connected with each others into space frame by using spot welding transversal reinforcement bars contacting with longitudinal reinforcement bars at frame. Allow using hooked transversal reinforcement bars bound with longitudinal bars at position that have transversal bars in welding steel frame.

If there are longitudinal reinforcements in each plane welding steel frame, should use hooked transversal reinforcement bars to tie intermediate longitudinal reinforcement bars in opposite frames, there is reinforcement tied like that far from each minimum longitudinal reinforcement and space of these tie reinforcements is not greater than 400 mm. Allow not placing tie reinforcement bars if side of section is not greater than 500 mm and the number of longitudinal reinforcements on that side are not greater than 4 bars.

8.7.3. In the eccentrically compressed members with the calculations of the indirect reinforcement in the form of the welded – wire fabric (made from the reinforcement of Groups CI, A- I, CCII, A-II, AIII with the dimension does not exceed 14 mm and Pb-I) or the helical and non-tension or hoop reinforcements, the following parameters should be considered:

- The dimension of the mesh cells shall not be less than 45 mm, but not be more than one third of the section edge and not more than 100 mm;

- The diameter of the twisted ring and or of the round ring shall not be less than 200mm;

- The mesh size shall not be less than 60 mm but not be more than one third of the less edge of the member's section and not more than 150 mm;

- The twisted step or the round step shall not be less than 40 mm, but not be more than one fifth of diameter of member's section and not more than 100 mm;

- Wire mesh, twist reinforcement (or round one) shall embrace all the structural longitudinal reinforcement bars;

- On reinforcing the ends of the eccentrically compressed members with the welded steel mesh, it is necessary to locate not less than 4 meshes on the section not less than 20d from the end of the member of the longitudinal reinforcement is the plain round bar and not less than 10 d with the ribbed reinforcing bar.

8.7.4. In the eccentrically compressed member, the diameter of hoop reinforcement in the steel frame must be taken less than 0.25d and not less than 5 mm with the d is the diameter of the maximum longitudinal reinforcement bar.

The diameter of the hoop reinforcement in the joint steel frame of the flexural member should be taken as follow:

- Not less than 5 mm when the height of member's section isn't more than 800 mm;

- Not less than 8 mm the height of member's section is more than 800 mm;

The correlation between the diameter of the horizontal and longitudinal reinforcement in the welded steel frame and the welded wire mesh is determined in accordance with the current regulations on welding.

8.7.5. In the girder structure with its height of more than 150 mm, as well as in the plate with many hollow holes (or in the similar structure with many frames) with its height of more than 300 mm, there should be placed with the horizontal reinforcement.

In the solid plate which is independent from its height, in the holed panel (or in the similar structure with many frames) with its height of more than 300 mm, it is not allowed to place the hoop reinforcement but the calculation requirements as given in 6.2.2.13 shall be ensured.

8.7.6. In the girder or plate structure as mentioned in the clause 8.7.5, the horizontal reinforcement shall be as follow:

- At the area next to the bearing: a distance of one fourth of span when the load is distributed evenly, whereas when there is the concentrated force, equal to the distance from the bearing to the concentrated force next to the bearing, but not less than one fourth of span, when the height of the member's section h, the step of horizontal reinforcement is taken as follow:

≤ 450 mm: not more than h/2 and not more than 150 mm

> 450 mm: not more than h/3 and not more than 500 mm

- On the remain part of span, when the height of the member's section is more than 300 mm, the step of hoop reinforcement shall be taken not more than 3/4h and not more than 500mm.

8.7.7. The horizontal reinforcement is located in a way that the shear must be anchored certainly at two ends by welding or adjoining with the longitudinal reinforcement, to ensure that the strengths of the joint and of the hoop reinforcement is similar.

8.7.8. In the holed compressed area, the horizontal reinforcement in the plate should be located with its step of not more than h/3 and not more than 200 mm, the width area where horizontal reinforcement are placed is not less than 1.5 h (where h is the thickness of plate). Anchoring these reinforcements according to the instructions in the clause 8.7.7.

8.7.9. The horizontal reinforcement of the short cantilever is positioned according to the horizontal direction or mitered direction. The reinforcement step must be not more than h/4 and not more than 150 mm (in which h is the height of cantilever).

8.7.10. In the member in twisting and bending concurrently, the hoop reinforcement shall be made a closed ring and anchored firmly at two ends (the overlap section of 30 d), and for the welded steel frame, all the horizontal reinforcement bars shall be welded to the longitudinal reinforcement bars at angles to make a closed ring, at the same time ensure that the strength of the joints and of hoop reinforcement is equal.

8.8. Steel reinforcement joints and available parts

8.8.1. Plain and ribbed reinforcements made from the hot-rolled steel, temperature processing steel of type A_T – IIIC and A_T-IVC and the conventional kinds of fabric steel, as well as the available parts should be applied with the butt welding and spot welding method to connect the reinforcement bars together or to connect the rolled steel plates together during processing them. It is allowed to use the automatic or semi-automatic arc welding as well as the manual welding according to the guidance in clause 8.8.5.

Butt connection of the cold-draw reinforcement bars of type A-III_B shall be welded before starting the cold-draw. For the reinforcement bars made from the hot-rolled steels of type CIV, A-IV (from the steel of mark 20CrMn2Zr), A-V and A-VII, thermo mechanical reinforced reinforcement bars such as AT-IIIC, A_T-IVC, A_T-IVK (from steel of mark 10MnSi2 and 08 Mn2Si), A_T-V (from the steel of mark 20MnSi) and A_T-VCK are only allowed to use the welding methods as regulated in the valid standards.

Do not allow to weld to connect the hot-rolled reinforcement bars of type CIV, A-IV (made from the steel of mark 80 Si), thermo mechanical reinforced reinforcement bars of type A_T-IV, A_T-IVK (made from the steel of mark 25Si2P), A_T-V (except the reinforcement made from the steel of mark 20 MnSi), A_T-VK, A_T-VIK and A_T-VII, high-strength fabric steel and cable for making reinforcement.

8.8.2. The types of welding connection and welding method of reinforcement bars and available parts shall be regulated, taking into account the use of structure, solderability of steel, eco-technical characteristics of connections and the technology capability of the producers.

Cross joints made by contacting spot welding method or adhesive arc welding methods must ensure that reinforcement bars of the mesh or the welded steel frame can put up with the stress which is not less than its calculating strength (connection with the standard strength) and this should be stated clearly in the drawing of reinforcement processing.

Cross joints with the strength not according to the calculating strength shall be used to fix reinforcement bars during the transporting process, concrete work or structure manufacturing process.

8.8.3. With the conditions of the workshop, when manufacturing the kinds of mesh or the welded steel frame or connecting longitudinal reinforcement bars along their length, the contacting spot welding and butt welding methods should be used and when manufacturing the available parts, automatic welding with the usage of welding compound for the angle welding and contacting butt welding for the overlap connection should be used.

8.8.4. When assembling the reinforcement products and the precast concrete reinforcement, it is the foremost preference to use the semi-automatic welding method to ensure the capability of quality control of connection.

8.8.5 When there aren't necessary welding equipments, it is allowed to use (in the conditions of the workshop and assembling) the cross welding connection, butt welding, overlap welding, angle welding to connect the reinforcement and available parts according to the arc welding method including the manual welding in conformity to the valid standards on welding the steel reinforcement and available parts. Do not allow to use the attaching arc welding in the cross connection with structural reinforcement bars of type CIII, A-III (made from steel 35 MnSi).

When using the manual arc welding to implement the welding connection calculated according to the strength, in the meshes, welding steel frame, the additional structural parts should be placed at the points that connect longitudinal reinforcement bars and the hoop reinforcement (such as cushion plate, joint plate, clamp, etc.).

8.9. Overlap connection of non-tension reinforcement (reinforcement tie)

8.9.1. Non-tension structural overlap connection is used to connect welded or tied steel frames, meshes with the diameter of tied bar not more than 36 mm.

Do not use the overlap in the tension area of the bent and eccentrically tensioned member at the positions where reinforcement's force – resistant capability is used out.

Do not use the overlap connection in the erect members where their entire section is tensioned (for example in the tie bar of the vault, the lower flange of frame) and well as in all cases of using the reinforcement of type CIV, A-IV upward.

8.9.2. When connecting all the tension and bent reinforcement bars as well as connecting the welded mesh and frame according the work direction, the length of the overlap section l shall not be less than the value *l*an determined according to the formula (189) and table 36.

8.9.3. The mesh or welded steel frame joints as well as the tension reinforcement bars of mesh, adjoined frame shall be positioned alternately. In which the structural reinforcement bar area, connected at a position or a distance of less than overlap section *l*, shall not more than 50% of the total area that the reinforcement bear the tension for the ribbed reinforcement and not more than 25% for the plain round reinforcement.

Connecting the reinforcement bars and the welded steel mesh is only allowed for the structure reinforcement as well as the position where the percentage of reinforcement to be used is not over than 50 %.

8.9.4. Joints of welded steel mesh made from the hot-rolled plain round steel of type CI, A-I according to the force-resistant direction must be done in such a way that on each connected mesh in the tension area on the overlap strength, there is not less than two horizontal bars which are welded with all longitudinal bars (Figure 26). Use the same connection for the overlap joints between the welded steel frames and the structural bars via one side and those made from any types of steel. The connection of welded mesh that made from the steel of type CII, A-II, CIII and A-III in the force-resistant direction is done without the horizontal reinforcement bar in the joint section at connected one or both meshes (Figure 27).

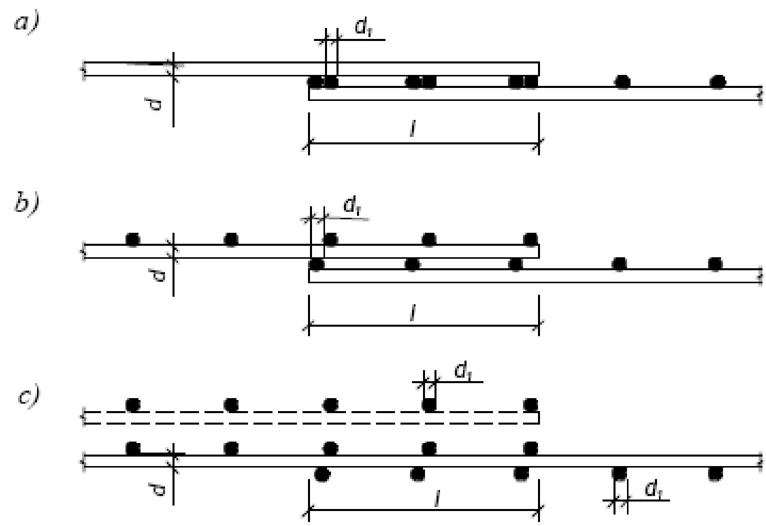


Figure 26.

Overlap connection (not welding) in the force -resistant direction for the welded mesh made from the plain round steel reinforcement

a – when the horizontal bar positioned to one side of the plane
b,c - when the horizontal bar positioned in different planes

8.9.5. Joints of the welded mesh according to the non – bearing direction are done by overlap connection with the overlap section (from the middle of the outermost structural reinforcement bars of each mesh).

- When the diameter of distributing bar (horizontal bar) is not more than 4 mm (Figure 28 a, b);………………………………………………………………………….. 50 mm

- When more than 4 mm (Figure 28 a, b): …………………………………… 100 mm

When the diameter of structural reinforcement is not less than 16 mm, the welded steel meshes according to the non –bearing direction are allowed to apply the butt placement and to use the specialized steel to make the connection. This additional adjoined mesh must be covered over the reinforcement in each side with a section not less than 15 d and not less than 100mm (Figure 28c).

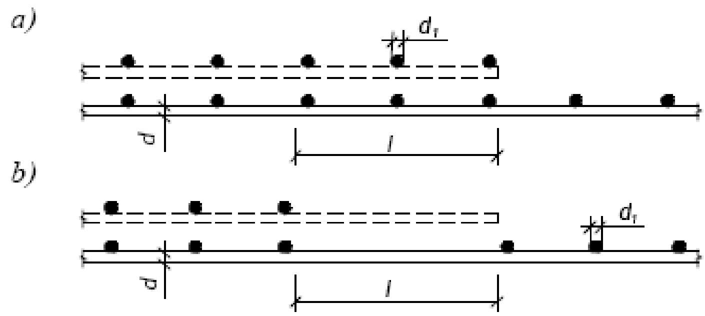


Figure 27. Overlap connection (non-welding) in the force–resistant direction for welded steel meshes made from the ribbed steel

a- Without horizontal bar in the adjoined section in one of the adjoined meshes

b- Without horizontal bar in the adjoined section in both two adjoined meshes

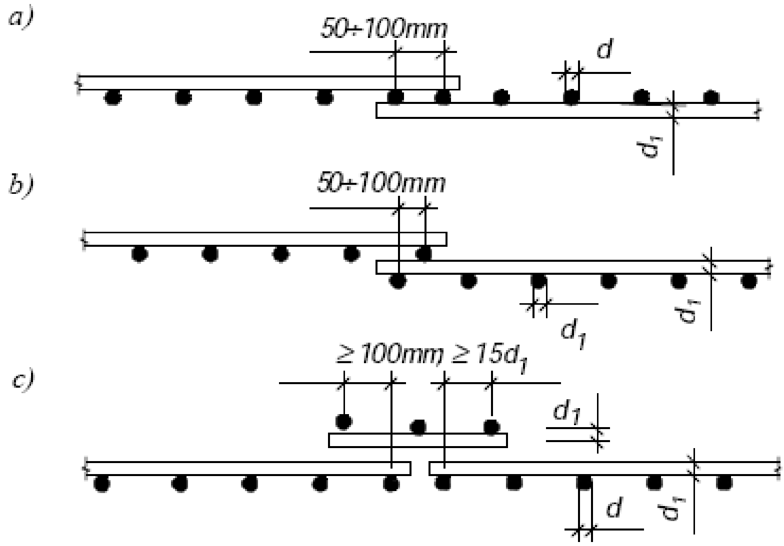


Figure 28. Connection of the welded mesh according to the direction of the distributing reinforcement

a – Overlap connection when the structural reinforcement bars position on the same plane

b - Overlap connection when the structural reinforcement bars position on different planes

c- closed packed joints of the meshes which are adjoined and covered with additional mesh

Welded steel mesh according to the non – bearing direction is allowed to position contiguously without overlap connection and the additional mesh in the following case:

- When positioning the welded steel mesh according to two directions that are perpendicular to each other.
- When at the joints, there is the additional structure reinforcement positioned according to the direction of the reinforcement distribution.

8.10. Joints of members of the built-up structure

8.10.1. When connecting the reinforcement members of the built-up structure, the internal force is driven from this member to another through the structural members of joints, through the available parts, the tamping concrete in the joints, through the concrete wedge or (for the compress member), directly through the concrete surface of the connected member.

The joints of the pre-stressed member, as well as the structures that require the impermeability must be done by the concrete that use the swelling cement.

8.10.2. Solid joints of the built-up structure shall be made monolithic by fill concrete into the connecting clearance between members. If when manufacture, making sure that placing closely surfaces together (for example: as when using the end of this member as the form for the one of another member), it is allowed to use the dry joints when there is only compressed force is driven through the joints.

8.10.3. Joints of the tension members must be done by:

a) Welding available parts with steel;

b) Welding the waiting reinforcements

c) Passing through the available tubes or the waiting clearances of the members that are connected with the cables or bolts and then tensioning them and tamping joints with the cement grout or the fine concrete;

d) Pasting members with the polymer mortar through the connecting parts made from the bar reinforcements.

8.10.4. Available parts must be anchored to the concrete by the anchor bars or by being welded to the structural reinforcement of member.

The available parts have anchor bars including plates (angle steel or gusset plates) are done with the angle welding or overlap welding with the anchor bars made from steel of type CII, A-II and CIII, AIII. The length of anchor bars of available parts under the tension force shall not be less than quantity l_{an} determined according to clause 8.5.2.

The length of anchor bars can be reduced with welding at the end of anchor plates or widening anchor heads with the with the diameter not less than 2d – for the reinforcement of type CI, A-I, CII, A-II and not less than 3d – for the reinforcement of type CIII and A-III. In those cases, the length of anchor bar is determined according to the pulling resistance and local pressing resistance of concrete and taken not less than 10 d (where d is the diameter of anchor bar, express in mm).

If the tension anchor are placed in perpendicular direction with the longitudinal bar of member and along them, there are likely the formation of cracks due to the basic internal force acting on the member, then the end of anchor bars must be reinforced with the additionally welded steel plates or by expanding the anchor heads.

Available parts stamped from the plate steel are constructed from the anchor feet with the firm adhesive positions (for example: in the type of sphere heads) and the functional part such as anchor plate (for example welded parts). Available parts stamped from the plate steel is from 4 mm to 8 mm thick and designed in such a way that discarded steel part while constructing the anchor feet is the smallest. The parts are calculated according to the strength of anchor feet and plate. The strength of each anchor part must be checked according to calculation of pull resistant and local press resistant concrete.

The length of plate of available parts is determined according to instruction in clause 6.2.6.3 and according to requirement for welding.

8.10.5. At the connected end of the eccentrically compress member (for example at the end of built – up bars), it is necessary to construct the indirect reinforcement in accordance with the instructions in clause 8.7.3.

8.11. Specific requirements for structure

8.11.1. The settling joints should be calculated beforehand in the cases of construction of house (building) on the non-uniform earth foundation (depressive foundation, etc.) at the positions where there are abrupt changes in load, etc.

If in any above case, the settling joints aren't be calculated beforehand, the foundation must be strong and solid enough to prevent the damages of the upper structure, or must have the special structure to achieve the above objectives.

The settling joints as well as the thermo-expansion joints in the concrete structure and reinforcement concrete must be continuously constructed throughout the structure to the foundation base. The thermo – expansion joints in the reinforcement frame structure shall be constructed by using the pair of pillars with middle joints to run through the surface of foundation.

The distance between settling joints, thermo-expansion joints in the concrete foundation and in the basement walls is allowed to be taken equally to that of joints between the upper structures.

8.11.2 . In the concrete structure, it is necessary to calculate beforehand the constructive reinforcement:

a) At the positions of abrupt changes in dimension of member's cross section

b) At the positions of height of wall (in the distance not less than 1m)

c) In the wall of concrete under or above the opening of each floor

d) In the moving carriages

e) At the edge with the stress less than that of eccentrically tensioned member, if the maximum stress in the section is determined as the same as elastic objects that exceeds 0.8 Tb, and the minimum stress is less than 1 Mpa or tensioned, whereas the reinforcement content μ is not less than 0.025%.

The requirements in this clause aren't applied for the members of the built-up structure examined during transportation and building up stages. In these cases, it is necessary to construct the reinforcement according to strength calculations.

If the calculations show that the strength of members is lost, at the same time with the appearance of concrete crack in the tensioned area, then it is necessary to take into account the requirements in clause 4.2.10 for the members with a few of reinforcement (do not take into account the work of tensioned concrete). If according to calculation with consideration of tensioned concrete, it is not necessary to construct reinforcement and experiences also show that it is not necessary to have the reinforcement during transporting and assembling, then it is not necessary to construct the constructive reinforcement.

8.11.3. Ensure that position for placement of reinforcement shall be in accordance with the design thanks to the building measures (such as plastic gauge placement, ring-joint made from the fine concrete, etc.)

8.11.4. The hole with large dimension in the plate, panel, etc shall be bordered with additional reinforcement with the section not less than the one of the necessary structural reinforcements (according to the direction of additional reinforcement placement) as the calculations for the solid plate.

8.11.5 When designing members of the built-up floor, it is necessary to determine beforehand the joints between the floor plates and tamped them with concrete. The width of joints is determined to assure the quality of their tamping and not less than 20 mm for members with their height not more than 250 mm and not less than 30 mm for the members with greater height.

8.11.6. In the members of the built-up structure, there should be the measure to lift them up: assembled lifting hook, waiting holes with steel tubes, fixed assembled hook made from bar steel, etc… Lifting hook must be made from the hot-rolled steel in accordance with the requirements of clause 5.2.1.8.

8.12. Additional instructions for the construction of prestressed reinforcement member

8.12.1. In the prestressed reinforcement member, it is necessary to ensure the adhesion between reinforcement and concrete by using the ribbed reinforcement, filling closely tubes, grooves and clearances with cement grout or fine concrete.

8.12.2. Diagram and the production method of the hyperstatic prestressed structures should be selected to ensure that when creating pre stress, there will no additional prestress in the structure to reduce the work capability of structure. Allow to locate temporary joints or couplings and to pour monolithically after stressing the reinforcement.

8.12.3. In the precast and cast-in-situ reinforcement structure, ensure the adhesion of prestressed members with concrete poured at the structural positions of the structure, as well as the anchoring of their heads together. In addition, the concurrent work of member in the horizontal direction should be also ensured by suitable measures (such as placement of horizontal reinforcement or member prestress in the horizontal direction).

8.12.4. A portion of the longitudinal reinforcement bar of member doesn't need the prestress if it has met the demands for calculations on cracks and transformation.

8.12.5 . When reinforcing locally at the adjacent area of tension steel anchoring as well as at positions that place the tensioning equipment, locate the available parts or add the horizontal reinforcement as well as increase the dimension of section at these segments.

8.12.6. If the tension longitudinal reinforcements are located concentrated upper, under and at the beginning of member, it is necessary to place additional tension or non-tension horizontal reinforcement.

The horizontal reinforcement must be stressed before stressing the longitudinal reinforcement with a force not less than 15% of the stressing force of the whole reinforcement at the tensioned area of bearing cross section.

The non-tension horizontal reinforcements must be anchored firmly by welding their ends to the available parts. The section of these reinforcements in the structure without the fatigue calculations must bear not less than 20% of the internal force in the tensioned longitudinal reinforcement at the area under the section of bearing, and for the structure with fatigue calculations, not less than 30%. The section of bearing is determined by calculations according to strength.

8.12.7. With the fibre reinforcement in the form of strands of fibre, it is necessary to calculate the clearances between each fibre or each strand of fibre (by placing spiral fibre steel in each strand or placing short bar at the anchor, etc.) to have the dimension large enough so that the cement gout can pass through fibre in the strand or the fine concrete can fill up the groove for cable.

8.12.8. Tension reinforcement (in the bar or cable form) in the holed member and the member with frames must be located along the axis of each frame of member, except for cases mentioned in the clause 8.6.5.

8.12.9. At each end of the prestressed member, it is necessary to place the additional hoop reinforcement or indirect reinforcement (welded steel mesh covering all the longitudinal reinforcement bars, hoop reinforcement, etc with the 5 or 10 cm step) on the length not less than 0.61p, and when in the member made from the light concrete of level B7.5 to B12.5 with the 5 cm step on the length not less than 1p (see clause 5.2.2.5) and not less than 20 cm for the member using the reinforcement without the anchor, and when with the anchoring structure – on the length equal to two times of the length of anchoring structure. Placement of anchor at the end of reinforcement is compulsory for the reinforcement which is tensioned on the concrete as well as for the reinforcement tensioned on the base, when the adhesion to concrete is not strong enough (plain fibre or multi-fibre cable), then the anchoring equipment must ensure to keep tightly the reinforcement in the concrete at all working periods of reinforcement.

When using the high-strength steel with rib or one-time cable, the hot -rolled ribbed bar reinforcement steel shall suffer the heat treatment to become the reinforcement tensioned on the base, then it is not necessary to place the anchor at the ends of tension reinforcement bars.

9. Calculation requirements and construction of reinforcement structure for major repair of house and buildings

9.1. General principles

9.1.1. This part specifies the design requirements for concrete structure and reinforcement of house and building (with or without being reinforced before) in each time of major repair.

This part specifies calculating principles of existing structure (examination calculation) as well as calculation and construction of structure to be reinforced.

9.1.2. Examination calculation of existing structures shall be done when there are changes in acting load, solution of building organization and the using conditions as well as when defects and damages are discovered in the structure in order to determine the load bearing capacity and the response to normal using conditions in the new working conditions.

9.1.3. Structures that do not meet the requirements in the examination calculation shall be reinforced.

The design of reinforced structures shall derive from the requirements for continuing or stopping temporary production.

9.1.4. Examination calculation of existing structures as well as calculation and construction of reinforced structure shall be done on the basis of design materials, manufacturing data and the building of these structures and the on-site survey data.

9.1.5. When there are no damages or defect that can reduce the load bearing capacity of structures as well as the deflection and expansion of crack beyond the allowable limit, it is allowed to carry out the examination calculations on the basis of design data (geometric dimensions of the structure cross section, compression (tension) strength level of concrete, concrete mark according to the compression (tension) strength, type of reinforcement, structure construction and diagram).

9.1.6. In cases of the requirements on the calculation according to the design materials do not meet the demands or without design materials as well as with defects and damages that can reduce the load bearing capacity of structures, with deflection and expansion of crack beyond the allowable limit, it is necessary to carry out the examination calculations including the on-site survey data of structures.

9.1.7. The on-site survey must show the data on geometric dimension of cross section, the allocation of the reinforcement in the structural member, concrete strength and steel type, the deflection of structure, width of cracks, defects and damages, load capacity and the static calculating diagram of structures.

9.1.8. The structure reinforcement is only considered in the cases where the existing structures do not meet the demands on examination calculations on the load bearing capacity or requirements on the normal using conditions. The structure reinforcement shouldn't be considered in the following cases:

- The factual deflection of structure is beyond the allowable limit (see clause 4.2.11) but isn't affecting the requirements on the normal using conditions and isn't changing its structural diagram;

- Structures have the differences in comparison with the requirements mentioned in the part 5 but the damages caused by those differences aren't detected during survey process although the structures have been used for a long time.

9.1.9. The calculations and construction of reinforced structures must be done on the basis of on-site survey data required in the clause 9.1.7.

9.2. Examination calculation

9.2.1. The examination calculations of concrete structure and reinforcement should be done according to the requirements given from part 4 to 8 and in this part.

9.2.2. Do not calculations according to the second limit states if the displacement and the width of cracks in the existing structure are under the allowable limit, and the internal force in the member section born due to the fact the new load does not exceed the internal force value caused by the real load acting on the structure.

9.2.3. In calculating, examine the section of structure if there are defects, damages or not, as well as the cross sections at which the survey detects the concrete area with strength 20% upward smaller than average one. The inclusion of defects and damages is also shown in the calculations by reducing the concrete or reinforcing steel area. It is necessary to include the effects of defects and damages to the strength characteristics, deformation of concrete; eccentricity of longitudinal force and the adhesion of concrete and reinforcement, etc.

9.2.4. The calculation characteristics are determined according to the Part 5 depending on the conventional compression strength level of concrete in the existing structure.

9.2.5. On carrying out the examination calculations of the data of designed materials, in case that the existing structure specifies the standard characteristic s of concrete as mark according to its strength, the conventional compression strength of concrete is taken as follow:

- For the heavy, fine and light concrete: as 80% of the standard cube sample strength corresponding to the mark according to compression strength.

- For the porous concrete: as 70% of the standard cube sample strength corresponding to the mark according to compression strength.

For the values of conventional compression strength level of concrete which are different from the ones mentioned in the clause 5.1.1.3, the calculation strength of concrete is determined by the linear interpolate.

9.2.6. On carrying out the examination calculations based on the results of on-site survey, the conventional compression strength level of concrete is determined according to the clause 9.2.5 but replacing the concrete mark with the real strength value of concrete according to the structure type, individual structure or each area of structure, obtained from the results of on-site survey, according to non-destructive experimental method or the method of testing sample taken directly from the structure.

9.2.7. Depending on the status of concrete, type of structure and their specific working conditions as well as methods of determining the concrete strength, with special basis, it is possible to use other methods to determine the concrete strength.

9.2.8. Calculating characteristics of concrete are determined depending on the type of steel used in the existing reinforcement structure according to instructions in part 2 including requirements mentioned in clause 9.2.9 and 9.2.10.

9.2.9. On carrying out the examination calculations of existing structure according to the design files based on the former standards, the standard strength of reinforcement Rsn is determined according to the Part 5. Then the standard strength of fibre steel of type B-I is taken as 390 MPa.

Calculating tension strength of reinforcement Rs is determined according to the formula:

$$R_s = \frac{R_{sn}}{\gamma_s}$$

In which: γ_s - confidence coefficient of reinforcement, taken as follow:

- When calculating according to the first limit status:

+ For the bar steel of type:

CI, A-I, CII, A-II, CIII, A-III: …………………………………………………1.15

CIV, A-IV, A-V and A-VI: …………………………………………………….1.25

+ For the fibre steel of type:

B-I, B-II, Bp-II, K-7, K-19: …………………………………………………..1.25

Bp-I: ……………………………………………………………………...1.15

- When calculating according to the second limit status:…………………………1.0

The calculating tension strength of horizontal reinforcement (hoop reinforcement and the oblique reinforcement bars) R_{sw} is determined by multiplying the value of calculating strength R_s obtained with the working condition coefficient γ_{si} (the value γ_{si} given in the part 5). The calculating tension strength of reinforcement R_{sc} (except for the reinforcement of type A-IIIB) taken equal to the calculating tension strength of reinforcement Rs, but not more than values given in the part 5. For the steel of type A-IIIB, the calculating tension strength R_{sc} is taken according to requirements of part 5.

In addition, it is necessary to take into account the additional working condition coefficient of reinforcement according to clause 5.2.2.4.

The value of calculating strength of reinforcement is rounded to 3 significant numbers.

9.2.10. On carrying out the examination calculations according to the results of testing the reinforcement sample taken from the on-site survey, the standard strength of the reinforcement is taken equal to the mean value of the real yield limit (or the conventional yield limit) obtained from the experiment of reinforcement sample dividing with the coefficient:

- For the reinforcement of type CI, A-I, CII, A-II, CIII, A-III, A-IIIB, CIV, A-IV …..1.1

- For the reinforcement pf other types: ………………………………………...1.2.

The calculating strength of reinforcement should be taken according to the requirements stated in the clause 9.2.9.

9.2.11. Depending on the number of testing samples and the status of reinforcement, with the certain basis, it is possible to use other methods to determine the calculating strength of reinforcement.

9.2.12. When there are no design materials and it is impossible to take the sample, it is allowed to take the calculating tension strength of reinforcement Rs depending on types of steel:

- For the plain round reinforcement, take R_s = 155 MPa;

- For the reinforcement with ribs along:

+ one side: R_s = 245 MPa;

+ two sides: R_s = 295 MPa;

Since then, the calculating strength of compressive reinforcement is taken as R_s, the calculating strength of horizontal reinforcement R_{sw} is taken as $0,8R_s$.

9.3. Calculations and construction of the structures to be reinforced

9.3.1. Requirements in this part are for designing and calculating the reinforcement structure reinforced with the shaped rolled steel, concrete or reinforcement concrete.

Reinforcement structures must be reinforced, designed to meet the requirements mentioned in the part 4 to part 8 of the standard TCXDVN 338: 2005 (when reinforcing with the shaped rolled steel) and the requirements in this part.

9.3.2. When designing the reinforced reinforcement concrete structure, it is necessary to ensure the working conditions concurrently of the reinforced part and the structure to be reinforced.

9.3.3. Calculations of reinforced structure should be implemented according to two stages:

a) Before the reinforced portion works: calculating the load capacity due to the weight of reinforce structure (calculating according to the first limit status only);

b) When the reinforced portion works: calculating the whole used load capacity (calculating according to both limit status);

It should be unnecessary to implement the calculation according to the second limit status if the used loads do not increase, the rigidity and the capacity against the crack of structure meet the requirements on using conditions, the reinforcement are implemented due to the detection of defects and damages.

9.3.4. For the heavily damaged structure (the destruction accounting for at least 50% of concrete section or at least 50% of reinforcement area), it is necessary to calculate the reinforced structural part that bear the whole acting load (excluding the working of structure to be reinforced).

9.3.5. The area of cross section of structure to be reinforced shall be determined based on its real weakness due to the erosion. The high strength fibre reinforcement in calculations are excluded when it is eroded into crack or suffering the internal erosion as well as eroded due to ion Cl^-.

9.3.6. Standard and calculating strengths of steel reinforced member are taken according to regulations in the TCXDVN 338:2005.

Standard and calculating strengths of concrete and reinforcement of the reinforcement structure to be reinforced and of the reinforced parts shall be taken following the instructions in the part 2 and according to the clauses from 9.2.4 to 9.2.12.

9.3.7. When designing structures to be reinforced, in principles, notice not to let the load during the reinforcement process exceed 65% of calculating load. In the too complicated cases or when it is impossible to reduce the load to the required level, allow to carry out the reinforcement in the status of greater load bearing of structure. Then calculating characteristics of concrete and reinforced reinforcement shall be multiplied with the working condition coefficient of concrete γ_{br1} = 0.9 and of reinforcement γ_{sr1} = 0.9.

9.3.8. In all cases, if the reinforced structure turns to be the hyperstatic system, take into account the elements in the clause 4.2.6.

9.3.9. The prestress values σ_{sp} vµ σ'_{sp} in the reinforced reinforcement S and S' should be taken according to the clauses 4.3.1 and 4.3.2.

In this case, the maximum prestress values of reinforcement σ_{sp} vµ σ'_{sp} are taken not more than 0.9 $R_{s,ser}$ for the bar steak and $0.7R_{s,ser}$ for fibre steel.

The minimum value of prestress in reinforcement is taken not less than and $0.49R_{s,ser}$.

9.3.10. On calculating the members to be reinforced with the prestressed bar steel, the loss of prestress should be determined according to clauses of 4.3.3 and 4.3.4.

On determining the loss due to the deformation of the anchor near the tensioning equipment, take into account the deformation due to the compression in the tensioning base. When there is no experimental data, take the deformation value as 4 mm.

9.3.11. The accuracy coefficient on tensioning should be determined according to the clause 4.3.5 by putting in the additional coefficient γ_{sp} depending on the features of reinforced construction as follow:

- For the horizontal cross bar and the tension reinforcement bar: ………………….0.85

- For the hoop reinforcement and the oblique straining bar: ………………………...0.75

9.3.12. For the bent and eccentrically compressed members that are reinforced with concrete and reinforcement, the calculation is made the same as for the solid members on conditions that it shall meet the requirements for calculation and construction to ensure the concurrent working between the old and new concrete. Then the unrepairable damages and defects of the members to reinforced (erosion or reinforcement fracture; erosion; layer division and the concrete damages, etc) that reduce the load bearing capacity of those members should be taken into account in the calculations such as examination calculation of structure before carrying out the reinforcement.

9.3.13. When in the structure reinforced with concrete or reinforcement concrete of different strength level, the value of calculating strength of concrete and reinforcement is put into the calculation according to strength with their calculating strength.

9.3.14. For the reinforcement members reinforced with concrete, reinforcement and reinforcement concrete, the calculation is made according to the strength condition for the section in perpendicular to the longitudinal axis of the member., for the inclined section and the space section (in case of existence of acting spiral moment), as well as the calculation of the local action of the load (compression, compression, piercing compression, fracture pulling) according to the requirements requirement in the part 6 and taking into account the presence of types of concrete and reinforcement with different strength level in the members to be reinforced.

9.3.15. Calculate the reinforcement concrete members reinforced with concrete, reinforcement or reinforcement concrete according to the conditions of formation, expansion and tightening of the cracks; according to the conditions of deformation in conformity with the requirements on the part 7 and additional requirements relating to the deformation and stress in the reinforcement concrete structure before take the reinforce part into operation, as well as relating to the existence of concrete and reinforcement of different strength level in the member to be reinforced.

9.3.16. The calculation of reinforcement concrete structure to be reinforced with unadhesive prestressed reinforcement is carried out according to the first and second limit states according to the requirements in the parts 7 and 8 and the additional requirements on the requirement for the unadhesive nature between the concrete and reinforcement.

9.3.17. The minimum dimension of section of member reinforced with concrete and reinforcement concrete shall be determined on the basis of calculation of the internal forces including the technology requirements and not less than the one according to requirements in the part 8 on the distribution of reinforcement and the thickness of concrete layer.

9.3.18. The compression strength level of reinforced concrete shall be taken equally to the concrete level of reinforced structure and not less than B15 for the upper structure and B12.5 for the foundation.

9.3.19. In cases that the reinforcement is estimated implemented after decrease the load on the structure to be reinforced, it is only to reload again when the reinforced concrete reaches the sufficient strength as in design.

9.3.20. On reinforcing with concrete and reinforcement concrete poured on-site, there should be measures (cleaning, make rough for the reinforced structure's surface, etc.) to ensure the strength of the joint area (joints) and the concurrent working between the reinforced part and the reinforced structure.

9.3.21. For the local reinforcement along the length of the damaged area, it is necessary to reinforce both the adjacent undamaged areas in the distance of not less than 500 mm and not less than:

- 5 times of the thickness of the reinforced concrete layer;

- length of the anchor of the reinforced longitudinal reinforcement;

- 2 times of greater dimension of section of reinforced member (for the bar structure).

9.3.22. Allow to reinforce the member using the non-tension reinforcement while the member is bearing load by welding the reinforced reinforcement to the current reinforcement if under the actions of the load during the reinforcement period of time., ensure the strength of the section of reinforced member, excluding the working of the reinforced reinforcements. Spot welding connection shall be distributed with the distance not less than 20d along the reinforcement bar.

ANNEX A

(Normative)

Concrete for the concrete and reinforcement concrete structure

A.1. The formula to determine the compression (tension) strength level of concrete

Correlation between the compression strength level and the immediate compression intensity of concrete is determined according to the formula:

$B = B_m (1\text{-}1.64v)$ (A.1)

Correlation between the tension strength level and the immediate tension intensity of concrete is determined according to the formula:

$B_t = B_{mt} (1\text{-}1.64v)$ (A.2)

In the formulas (A.1) and (A.2):

B_m and B_{mt} - statistic average values of the immediate compression and tension intensities respectively are determined as follow:

$$B_m(B_{mt}) = \frac{n_1 B_1 + n_2 B_2 + ... + n_n B_n}{n_1 + n_2 + ... + n_n} \qquad (A.3)$$

In which: n_1, n_2, …, n_n – number of standard samples with the compression and tension intensity B_1, B_2,…, B_n; respectively.

ν – changing coefficient of intensity of standard samples, depending on the advance of technology of concrete production: ν = 0.135 for the compression case, ν = 0.165 for the tension case.

A.2. Correlation between the strength level and mark of concrete according to the intensity:

Table A.1. Correlation between the compression strength level and mark of concrete according to the compression intensity

The compression strength level	The average intensity of the standard sample, MPa	Mark in accordance with the compression intensity	The compression strength level	The average intensity of the standard sample, MPa	Mark in accordance with the compression intensity
B3.5	4.50	M 50	B35	44.95	M450
B5	6.42	M75	B40	51.37	M500
B7.5	9.63	M100	B45	57.80	M600
B10	12.84	M150	B50	64.22	M700
B12.5	16.05	M150	B55	70.64	M700
B15	19.27	M200	B60	77.06	M800
B20	25.69	M250	B65	83.48	M900
B22.5	28.90	M300	B70	89.90	M900
B25	32.11	M350	B75	96.33	M1000
B27.5	35.32	M350	B80	1.02.75	M1000
B30	38.53	M400			

Table A.2. Correlation between the tension strength level and mark of concrete according to the tension intensity

The tension strength level	The average intensity of the standard sample, MPa	Mark in accordance with the compression intensity
B_t 0.4	0.55	-
B_t 0.8	1.10	K10
B_t 1.2	1.65	K15
B_t 1.6	2.19	K20
B_t 2.0	2.74	K25
B_t 2.4	3.29	K30
B_t 2.8	3.84	K35
B_t 3.2	4.39	K40
B_t 3.6	4.94	-
B_t 4.0	5.48	-

Note : In the tables A.1 and A.2:

Note 1: Values of mark of concrete in accordance with compression (tension) intensity is rounded to the nearest values but inclining to safety;

Note 2: Values given in the tables are applied for heavy, fine, light and hollow concretes

A.3. Correlation between the standard compression intensity of concrete R_{bn} (cylindrical intensity) and the compression strength level of concrete.

Correlation between the standard compression intensity of concrete R_{bn} (cylindrical intensity) and the compression strength level of concrete is determined according to the following formula:

+ For the heavy, fine, light and hollow concretes:

$$R_{bn}/B = (0.77 - 0.001B) \qquad (A.4)$$

But not less than 0.72.

For the porous concrete:

$$R_{bn}/B = (0.95 - 0.005B) \qquad (A.5)$$

Value R_{bn} is calculated according to the formula (A.4) and (A.5) in Table 12 of this standard and has been rounded.

ANNEX B

(Informative)

SEVERAL COMMON STEEL AND INSTRUCTIONS

B.1 Classification of steel according to yield limits of some types of steels

Table B.1- Common steels

Conversion group	Types	Shape of cross section	Running limit for conversion MPa	Symbols	Production country and standard	Yield limit MPa	Strength limit Mpa
According to the real running limit	Hot rolled carbon steel	Plain	**235**	***CI*** ***A-I***	***Vietnam (TCVN 1651 : 1985)*** ***Russia (GOST 5781-82*)***	***235 min.***	***380 min.***
				SR235	Japan (JIS G 3112 -1991)	235 min.	380 ÷ 520
			250	BS 4449 :1997 gr.250	Britain (BS 4449 : 1997)	250 min.	287,5 min.
				AS 1302–250R	Australia (AS 1302-1991)	250 min.	–
				AS 1302–250S		250 min.	–
			295	SR295	Japan (JIS G 3112 -1991)	295 min.	380 ÷ 520
		Streaked (ribbed)	295	SD295A	Japan (JIS G 3112 -1991)	295 min.	440 ÷ 600
				SD295B	Japan (JIS G 3112 -1991)	295 ÷ 390	440 ÷ 600
			300	***CII*** ***A-II***	***Vietnam (TCVN 1651 : 1985)*** ***Russia (GOST 5781-82*)***	***300 min.***	***500 min.***
			300	A615M gr. 300	America (ASTM A615M-96a)	300 min.	500 min.
			335	RL335	China (GB 1499-91)	335 ÷ 460	510 min.
			345	SD345	Japan (JIS G 3112 -1991)	345 ÷ 440	490 min.
			390	SD390	Japan (JIS G 3112 -1991)	390 ÷ 510	560 min.
			390	***CIII*** ***A-III***	***Vietnam (TCVN 1651 : 1985)*** ***Russia (GOST 5781-82*)***	***600 min.***	***600 min.***
			400	AS 1302–400Y	Australia (AS 1302-1991)	400 min.	–
			420	A615M gr. 420	America (ASTM A615M-96a)	420 min.	620 min.
			460	BS 4449 : 1997 gr.460A	Britain (BS 4449 : 1997)	460 min.	483 min.
				BS 4449 :1997 gr.460B			497 min.
			490	SD490	Japan (JIS G 3112 -1991)	490 ÷ 625	620 min.
			520	A615M gr. 520	America (ASTM A615M-96a)	520 min.	690 min.
			540	***A-IIIB***	***Russia (GOST 5781-82*)***	***540*** min.	**–**
			540	RL540	China (GB 1499-91)	540 min.	835 min.

NOTE: The above steel symbols in this table only contain original symbol that gives mechanical properties, do not note this symbol for giving the other characteristics. Full symbol is given in the corresponding national standards of each nation.

Table B.2. High strength steels

Conversion group	Types	Shape of cross section	Running limit for conversion MPa	Symbols	Production country and standard	Yield limit MPa	Strength limit Mpa
According to conventional running limit	Hot rolled carbon bar steel	Streaked	590	RL 590	China (GB 1499-91)	590 min.	885 min.
			590	**CIV** **A-IV**	**Vietnam (TCVN 1651: 1985)** **Russia (GOST 5781-82*)**	**590 min.**	**900 min.**
			785	SBPR 785/1030	Japan (JIS G 3109-1994)	785 min.	1030 min.
			788	***A-V***	**Russia *(GOST 5781-82*)***	***788 min.***	***1000 min.***
			830	ASTM A722Mgr.1035	America (ASTM A722M-98)	830 min.	1035 min.
			835	RE (RR) -1030	Britain (BS 4486 :1980)	835 min.	1030 min.
			930	SBPR 930/1080	Japan (JIS G 3109 -1994)	930 min.	1080 min.
			930	SBPR 930/1180	Japan (JIS G 3109 -1994)	930 min.	1180 min.
			980	*A-VI*	Russia *(GOST 5781-82*)*	*980 min.*	*1250 min.*
			1080	SBPR 1080/1230	Japan (JIS G 3109-1994)	1080 min.	1230 min.
			1175	*AT-VII*	Russia *(GOST 10884-94)*	*1175 min.*	*1400 min.*
	Fibre steel	One fibre steel	1300	wire - 1570 - 7	Britain (BS 5896 :1980)	1300 min.	1570 min.
			1390	wire - 1670 - 7		1390 min.	1670 min.
			1390	wire - 1670 - 6		1390 min.	1670 min.
			1470	wire - 1770 - 6		1470 min.	1770 min.
			1390	wire - 1670 - 5		1390 min.	1670 min.
			1470	wire - 1770 -5		1470 min.	1770 min.
			1350	wire - 1620 - 4.5		1350 min.	1620 min.
			1390	wire - 1670 - 4		1390 min.	1670 min.
			1470	wire - 1770 - 4		1470 min.	1770 min.
			1200	***3Bp1200***	**Russia *(GOST 7348-81*)***	***1200 min.***	***1470 min.***
			1300	***4Bp1300***		***1300 min.***	***1570 min.***
			1400	***5Bp1400***		***1400 min.***	***1670 min.***
			1400	***6Bp1400***		***1400 min.***	***1670 min.***
			1400	***7Bp1400***		***1400 min.***	***1670 min.***
			1500	***8Bp1500***		***1500 min.***	***1780 min.***
	Fibre cable	7-fibre	1420	7-wire standard-1670-15.2	Britain (BS 5896 :1980)	1420 min.	1670 min.
			1500	7-wire standard-1770-12.5		1500 min.	1770 min.
			1490	7-wire standard -1770 -11		1490 min.	1770 min.
			1500	7-wire standard -1770 - 9.3		1500 min.	1770 min.
			1550	7-wire supe -1770 - 15.7		1550 min.	1770 min.
			1580	7-wire supe -1860 - 12.9		1580 min.	1860 min.
			1570	7-wire supe -1860 - 1.3		1570 min.	1860 min.
			1580	7-wire supe -1860 - 9.6		1580 min.	1860 min.
			1550	7-wire supe -1860 - 8.0		1550 min.	1860 min.
			1450	7-wire drawn -1700 - 8.0		1450 min.	1700 min.
			1550	7-wire drawn -1820 - 5.2		1550 min.	1820 min.
			1560	7-wire drawn -1860 - 2.7		1560 min.	1860 min.
			1400	*K7-1400*	Russia *(GOST 13840-81)*	*1400 min.*	*1670 min.*
			1500	*K7-1500*		*1500 min.*	*1770 min.*
			1550	*ASTM A416Mgr.1725*	*America (ASTM A416M-98)*	*1550 min.*	*1725 min.*
			1670	*ASTM A416Mgr.1860*	*America (ASTM A416M-98)*	*1670 min.*	*1860 min.*
		19-fibre	*1500*	*K19-1500*	Russia *(TU 14–4–22-71)*	*1500 min.*	*1770 min.*

NOTE: The above steel symbols in this table only contain original symbol that gives mechanical properties, do not note this symbol for giving the other characteristics (some symbol including diameter, ex 7- wire super-1860-12.9). Full symbol is given in the corresponding national standards of each nation.

B.2. Equivalent steel conversion method

B.2.1. The using of the steel types which are different from the steel according to the TCVN (or GOST of Russia) must be on the basis of the equivalent standards of that type of steel regarding the requirements for usage of construction steel. Then, it is necessary to understand clearly the main technical norms mentioned in the clause 5.2.1.1. (chemical composition and the manufacturing method meeting the requirements for construction steel; norms on intensity; yield limit, strength limit and the changing coefficient of those limits; elastic modules, maximum expansion, plasticity, weldability and the changes of mechanical properties when increasing or decreasing the temperature for the high or low heat bearing capacity; fatigue limit for the repeating load bearing structure, etc.). Besides, it is necessary to know the shapes of cross section: plain round, streaked (ribbed), fibre or cable steel.

In order to convert types of steel to the equivalent types, types of steel are classified into two groups: the one with the clear real yield limit and the one with the unclear real yield limit. For the type of steel with the clear real yield limit, base on the conventional yield limit regulated in the equivalent standards to convert.

B.2.2. The using of the steel types which are different from the steel according to the TCVN (or GOST of Russia) must be on the basis of real yield limit (or the conventional yield limit) to convert to the most equivalent steel types but inclining to safety.

B.3. Application of safety coefficient

B.3.1. The using of calculating coefficient not according to TCVN (or GOST of Russia) must comply the following instruction for each coefficient:

B.3.1.1. Confidence coefficient of reinforcement γ_s :

When calculating according to the first limit state:

+ For the steel types with the yield limit, the value of which is not more than 300 MPa: take γ_s = 1.1

+ For the steel types with the conventional yield limit, the value of which is more than 600 MPa: take γ_s = 1.2

+ For the steel types with the yield limit, the value of which is ranging from 300 to 600 MPa: take γ_s according to the linear interpolate between two values of 1.1 and 1.2.

When calculating according to the second limit state:

Take γ_s = 1.0

B.3.1.2. Working condition coefficients γ_{si}

When calculating according to the first limit state:

a) The coefficients γ_{s3} is included until the structure bears the repeating load. Do not allow to apply the values of γ_{si} given in the Table 24 for reinforcements which are different from other types of reinforcement in this table. If using the other types of reinforcement, ensure to know their fatigue limit.

b) The coefficients γ_{s4} is included until the structure bears the repeating load and there is welding connection for reinforcement.

c) The coefficients γ_{s6} is included until the high-strength reinforcement (with conventional running limit) works in the higher conditions in comparison with the conventional yield limit (see 6.2.2.4): to determine the γ_{s6} in the formula (26), the coefficients η is taken as follows:

+ For the cable steel: η = 1.15;

+ For the bar steel with the standard tension intensity of 590 MPa: η = 1.20;

+ For the bar steel with the standard tension intensity of 800 MPa: η = 1.15;

+ For the bar steel with the standard tension intensity of more than 1000 MPa: η = 1.10;

+ For the bar steel with the standard tension intensity between the above distance, η is taken in accordance with the linear interpolate.

When the welding joints on the member's area with the bent moment of over 0.9 M_{max} (M_{max} is the maximum calculating moment), the value of coefficient γ_{s6} for the reinforcement with the conventional yield limit of less than 800 MPa is taken not more than 1.1; for the reinforcement with the conventional yield limit of more than 1000 MPa, not more than 1.05; if the yield limit value in the range from 800 MPa to 1000 MPa, not more than the value η in accordance with the linear interpolation with the corresponding values of the conventional yield limit.

d) Coefficient γ_{s7} is taken as 0.8 for the plain round steel used to be the horizontal reinforcement of the member made from the light concrete of level B7.5 and lower (see Table 15);

When calculating according to the second limit state:

The calculating intensity of reinforcement when calculating according to the limit states of second group $R_{s,ser}$ is brought into the calculation with the work condition coefficient γ_{si} = 1.0.

B.3.1.3. Value σ_{sR}

In the formula (25), the value σ_{sR} is determined depending on the types of steel (with the yield limit or conventional yield limit and cable steel type):

+ For the steel with the yield limit (bar steel or normal fibre steel): $\sigma_{sR} = R_s - \sigma_{sp}$

+ For the steel with the conventional yield limit: $\sigma_{sR} = R_s + 400 - \sigma_{sp} - \Delta\sigma_{sp}$ (for the fibre and cable steel, $\Delta\sigma_{sp} = 0$);

When using tension and non-tension reinforcement, σ_{sR} is determined according to the tension reinforcement. When using the tension reinforcement with the different strength limits, allow to take the maximum value of σ_{sR} among those strength limit values.

B.3.1.4. Values $\Delta\sigma_{spi}$ and β in the clause 6.2.2.19:

When causing the prestress for the bar reinforcements with the conventional yield limit by the mechanical method, as well as by the automatic tempo-electrical method or the automatic tempo mechanical method:

$$\Delta\sigma_{spi} = 1500\frac{\sigma_{spi}}{R_{si}} - 1200 \geq 0$$

$$\beta = 0.5\frac{\sigma_{spi}}{R_{si}} + 0.4 \geq 0.8$$

When causing the prestress for the bar reinforcements with the conventional yield limit by other methods, as well as causing the prestress for the fibre and cable reinforcement with the conventional yield limit by any method, the value $\Delta\sigma_{spi} = 0$ and the coefficient $\beta = 0.8$.

B.3.1.5. Value η_r

In the formula (45), η_r is taken as follow:

+ For the reinforcement with the real yield limit: $\eta_r = 1.0$;

+ For the reinforcement with the conventional yield limit (including bar, fibre and cable steel): $\eta_r = 1.1$;

B.3.1.6. Coefficients η and θ in the formula (55):

The coefficient η is taken as 25 for the high- strength steel with the conventional yield limit

The value θ is taken not less than 1.0 and not more than 1.6.

B.3.1.7. Value $\sigma_{sc,u}$

In the formula (57) for the types of reinforcement with the conventional yield limit not more than 800 MPa, $\sigma_{sc,u}$ is taken not more than 1200 MPa, when the conventional yield limit is less than 800 MPa, $\sigma_{sc,u}$ is taken not more than 900 MPa.

B.3.1.8. Coefficients φ_{b2}, φ_{b3} and φ_{b4}

In the clause 6.2.2.3: When calculating the structure using the longitudinal reinforcement with the conventional yield limit, the coefficients φ_{b2}, φ_{b3}, as well as φ_{b4} (clause 6.2.3.4) must be multiplied with the coefficient 0.8.

B.4. Construction requirements

B.4.1. The thickness of the protecting concrete layer

B.4.1.1 In the clause 8.3.4: The thickness of the protecting concrete layer at the ends of prestressed members along length of the stress driving section (see clause 5.2.2.5) must be taken not less than:

+ For the bar steel (of high strength) with the conventional yield limit: …………… 3d

+ For the cable reinforcement: ………………………………………………………… 2d

(where, d is expressed in mm).

Besides, the thickness of the protecting concrete layer at the above mentioned region shall not be less than 40 mm for all types of bar reinforcements and not less than 30 mm for the cable reinforcement.

B.4.1.2. in the clause 8.6.2: In the bent members made from the light concrete using the reinforcement equivalent to CIV, A-IV and lower, the diameter of the longitudinal reinforcement shall not be more than:

+ For the concrete with the compression strength level from B12.5 downward: …16 mm

+ For the concrete with the compression strength level from B15 to B 25: ……… 25 mm

+ For the concrete with the compression strength level from B 30 upward: ……… 32 mm

+ For the reinforcement of higher types, the limit diameter of the reinforcement bar must be in accordance with the current regulations

B.5. Regulations on the welding of reinforcement

The welding of reinforcement shall comply the requirements on welding reinforcement according to the corresponding standards for each selected type of steel: welding types, welding method, etc.

B.6. Regulations on connecting reinforcement

They shall comply the requirements in the part 8 of this standard.

ANNEX C

(Normative)

DEFLECTION AND TRANSPOSITION OF STRUCTURE

C.1. Scope

C.1.1. This part specifies the limit values of deflection and transposition of the force bearing structure and the covering of the house and building when calculating according to the second limit states.

C.1.2. Regulations in this part aren't applied fro the public irrigation, traffic constructions, nuclear electric factory as well as of the electricity transporting poles, outdoor distributing equipments and the antenna the communication constructions.

C.2. General instructions

C.2.1. The calculations of the building structures according to the deflection (convexity) or transposition shall meet the hereafter condition:

$$f \leq f_u \qquad \text{(C.1)}$$

In which:

f - The deflection (convexity) or transposition of parts of structure (or the whole structure) is determined in a way that the elements affecting their values as mentioned in the item C.7.1 to C.7.3 are taken into account;

f_u - The limit deflection (convexity) or transposition specified in this regulation;

The calculation should do from the following requirements:

a) Requirements on the technology (ensuring the condition for normal use of the technological equipments, lifting and moving equipments, measuring and examining devices, etc.);

b) Requirements on construction (ensuring the integrity of adjacent structure and their joints, ensuring the regulated inclination);

c) Requirements on the psychophysiology (preventing the harmful effects and the uncomfortable feeling when the structure fluctuates);

d) Aesthetic and psychological requirements (ensuring that the external shape of the structure makes good impression, eliminates the dangerous feelings).

When calculating, these above requirements shall be met individually and independently.

Limitations on the fluctuation of structure shall be regulated according to the requirements in the item C.7.4.

C.2.2. Calculating situations in which it is necessary to determine the deflection, transposition and their corresponding loads as well as requirements relating to the initial convexity given in the item C.7.5.

C.2.3. The limit deflection of the structural parts such as roof and floor specified according to the requirements on technology, construction and psychophysiology is calculated from the bent axis of the member corresponding to state at the time of putting load that causes the certain deflection, and if according to the aesthetic and psychological requirements, is calculated from the straight line that connects from the joints of bearings of members (see item C.7.7).

C.2.4. The deflection of structural parts according to the aesthetic and psychological requirements is unlimited of it is difficult to detect or not clearly affect the external shape of the structure (for example: the structure with the flange bar hanging low or uplifting, thin roof, inclining canopy). The deflection according to above requirements is unlimited for the floor and rood structures in the room where people rarely come and stay long (for example the transforming station and shelf roof).

Note: For all kinds of roof and floor, the integrity of the roof covering layer must be ensured according to the requirements on constructive measures (for example using the creep mechanism or making the roof structure to work according to the continuous diagram).

C.2.5. Confidence coefficient on load for all loads and the moving coefficient for the loads of trucks, electric trucks and the cranes shall be taken as 1.

C.2.6. For the parts of housing and building structures in which their deflection and transposition are not mentioned in this standard and others, the deflection according to the longitudinal and horizontal directions due to the frequent, temporarily long-term and short -term loads shall not exceed 1/150 of span or 1/75 of cantilever’s length.

C.3. Limit deflection according to the longitudinal direction of members

C.3.1. Limit deflection according to the longitudinal direction of members and corresponding load used to determine that deflection is given in the Table C.1. The requirements for slots between members given in the item C.7.6.

Table C.1. Limit deflection according to the longitudinal direction f_u and the corresponding load to determine that deflection according to the longitudinal direction

Member's structure	**According to requirements on**	**Limit deflection according to the longitudinal direction f_u**	**Load to determine that deflection according to the longitudinal direction f**
1. Girder of crane and hanging bridge is controlled - From the floor, including - From cabinet equivalent to the working conditions Group 1 K – 6K Group 7K Group 8K	Technology Psychophysiology and technology	$l/250$ $l/400$ $l/500$ $l/600$	Due to one crane Ditto Ditto Ditto
2. Girder, frame, plate, beam, panel (including the ribs of plate and panel): a. Visible roof and floor with the aperture *l*: $l \leq 1\ m$ $l = 3\ m$ $l = 6\ m$ $l = 24(12)\ m$ $l \geq 36(24)\ m$	Aesthetics – psychology	$l/120$ $l/150$ $l/200$ $l/250$ $l/300$	Frequently and temporarily long-term
b. Roofing floor and floors between the storey with dividing walls below	Construction	Taken according C.7.6	To reduce the slots between the structural parts of the structure and the dividing walls
c. Roofing floor and floors between storey upper with the parts subjected to the separating actions (cross bar, floor base layer,	Construction	$l/150$	Acting after completing the dividing walls, floor base layer

Member's structure	**According to requirements on**	**Limit deflection according to the longitudinal direction** f_u	**Load to determine that deflection according to the longitudinal direction** f
dividing partition)			and the cross bar
d. . Roofing floor and floors between storey with purchase, bridge crane controlled from:			
+ floor	Technology	The smaller value between the two values of l/300 or a/150	The temporary load including the one due to one crane or purchase on one railway
+ cabin	Psychophysiology	The smaller value between the two values of l/400 or a/200	The load due to one crane or purchase on one railway
e. The floor under action of: - The movement of heavy objects, materials, parts and mechanical parts and other moving loads (in which there is a moving load on the unrailed floor)	Psychophysiology	l/350	Take the more inadvantagous value between the two values: + 70 % if the whole standard temporary load + load of a loading truck
- Load moving on the rail:			
+ narrow way		l/400	Load of a rail running on the railways
+ large way		l/500	Ditto
3. Parts of stairs, stair plates, reposing angle and floor landing, string , balcony, loggia	Aesthetics – psychology	As in subclause 2a	
	Psychophysiology	Defined as in requirements of subclause **C.3.4**	
4. Stair plates, reposing angle and floor landing, whose	Psychophysiology	0,7 mm	Concentrated load of 1kN at

Member's structure	**According to requirements on**	**Limit deflection according to the longitudinal direction** f_u	**Load to determine that deflection according to the longitudinal direction** f
deflection does not hinder the adjacent parts			the middle of span
5. Lintel, wall plate on the window and the door (beam of the glass partition)	Construction	$l/200$	To reduce the clearance between the structural members and the chocking parts of windows and doors under members
	Aesthetics - psychology	As in subclause 2a	

Symbols in the table:

l : calculating span of member

a – beam step or the frame connecting with the path of the bridge crane

Note 1: *For the cantilever l, it is taken as the two times of the length reaching the cantilever.*

Note *2: For the immediate values of l in the item 2a, the limit deflection is determined equal to the linear interpolate including the requirements in the C.7.7.*

Note *3: In the item 2a, number in brackets ( ) is taken when the room's height is up to 6 m.*

Note *4: The calculation characteristics of deflection according to item 2d are mentioned in the C.7.8.*

Note *5: When taking the limit deflection according to the aesthetic – psychological requirements, allow that the span's length l is taken equal to the distance between the internal sides of the structural walls (or columns).*

C.3.2. The distance (clearance) from the top of the bridge crane to the bottom point of the deflected force bearing structure of roof (or the objects connecting them) is taken not less than 100 mm.

C.3.3. For the roof members, ensure that when including their deflection, the slope of roof is not less than l/200 according to one of directions (except cases mentioned in other standards).

C.3.4. Limit deflection according to psycho physiological the requirements of floor members (beam, bar and plate), stairs, balcony, logia, rooms in houses and public house, rooms of the workshop should be determined according to the formula:

$$f_u = \frac{g(p + p_l + q)}{30n^2\left(bp + p_l + q\right)} \qquad \text{(C.2)}$$

in which:

g – gravitation acceleration;

P – standard value of load due to the human weight causing the oscillation, taken as in the table C.2.;

P_1 – standard value which have been minus the floor load, taken according to the table 3, TCVN 2737: 1995 and the table C.2;

q – standard value of the load due to the weight of calculated members and the structure that bear against them;

n – frequency of increasing load when people walk to and fro, taken according to the Table C.2;

b – coefficient, taken according to Table C.2.

Deflection shall be taken according to the total loads $\psi_{Al} + p_l + q$

In which: $\psi_{Al} = 0.4 + 0.6/\sqrt{A/A_1}$ with A is the load bearing object, $A_1 = 9m^2$

Table C.2. Coefficient b

Room type **(according to Table 3, TCVN 2737:1995)**	p **kPa**	p_l **kPa**	n **Hz**	b
Point 1, 2, except the meeting room and the class room Point 4, 6b, 14b, 18b	0.25	Taken according to table 3 in TCVN 2737: 1995	1.5	$125\sqrt{\frac{Q}{\alpha pal}}$
Point 2: class room and the meeting room Point 7, 8 except the dancing room, stand Point 14a, 15, 18a, 20	0.5	ditto	1.5	$125\sqrt{\frac{Q}{\alpha pal}}$
Point 8: dancing room, stand Pont 9	1.5	0.2	2.0	50
Note: *Q – weight of a person taken as 0.8 kN.* *α - coefficient taken as 1.0 for the member that is calculated according to the beam diagram, taken as 0.6 for the remaining members (for example the three or four sided supporting plate).* *a – step of beam, bar, width of plate, m.* *l – calculation step of member, structure.*				

C.4. Limit deflection according to the horizontal direction of pillar and breaking structure due to the crane's load

C.4.1. Deflection according to the horizontal direction of house pillar with bridge crane, viaduct as well as the beam of bridge crane and the breaking structure (beam and frame) taken according to the Table C.3 but not less than 6 mm.

The deflection shall be re-examined at the upper height of the bridge crane's rail according to the breaking force of a bridge crane acting to the direction that cross the path of bridge crane, not including the declination of foundation.

C.4.2. The limit inward movement according to the horizontal direction of the path of outdoor bridge crane, viaduct due to the load according to the horizontal and longitudinal direction of a bridge crane (not including the declination of foundation) in accordance with the technical requirements shall be taken as 20 mm.

Table C.3. Limit deflection according to the horizontal direction f_u of the pillar of house with the bridge crane, viaduct, beam of bridge crane and breaking structure

Group of working regulations of bridge crane	Limit deflection f_u of		
	Pillar		beam of bridge crane and breaking structure, house and leading bridge (including indoor and outdoor)
	Outdoor house and viaduct	Indoor viaduct	
1K – 3K	h/500	h/1500	h/500
4K – 6K	h/1000	h/2000	h/1000
7K – 8K	h/2000	h/2500	h/2000

Note:

h- height from the upper surface of foundation to the top of railway of bridge crane (for the one storey house and the outdoor or indoor leading bridge) or the distance from the axis of floor beam to the top of railway of bridge crane (for the upper storey of the multi-storey building).

L – calculation span of the member (beam).

C.5. Transposition according to the horizontal direction and the deflection of frame house, individual members and the conveyor belt supports due to the load of wind, the declination of foundation and the impact of temperature and climate

C.5.1. Limit horizontal transformation of the frame house is taken according to the construction requirements (ensure that the chocking layer of frames such as wall, separating wall, parts of door and window is undamaged) which are given in the Table C.4., instructions about the determination of transformation given the clause C.7.9.

C.5.2. horizontal transformation of the frame house to be determined shall be included with the declination (the turning) of foundation. In which, the loads due to the weight of equipment, wood furniture, people, occupying materials are only included when all these loads are piled evenly on the entire floors of the multi-storey building (it is decreasing depending on the numbers of storey), except for the foreseen cases with other loading measures under the normal using conditions.

The declination of foundation to be determined including the wind load is taken about 30% of standard value.

C.5.3. horizontal transformation of the non-frame house due to the wind load is unlimited if the wall, separating wall and connecting parts have been calculated according to the strength and the crack resistant capability.

C.5.4. Limit deflection according to the horizontal direction according to the construction requirements of pillar and the gable beam as well as panels of hanging walls should be taken equal to l/200, in which l is the calculating length of pillar or panel.

Table C.4 Limit transposition according to the horizontal direction f_u according to design requirement

House, wall and partition wall	Bond among wall, partition wall on frame of house	Limit transposition f_u
1.Multi-storey house.	Any	$h/500$
2. One storey of multi-storey buildings	Soft	$h_s/300$
a) Wall, brick, gypsum concrete partition, concrete reinforcement panel	Hard	$h_s/500$
b) Wall covered with natural stones, made from the ceramic block or glass	Hard	$h_s/700$
3. One storey house (with the itself loading wall) h_s, m $h \leq 6$		$h_s/150$
$h = 15$	Soft	$h_s/200$
$h \geq 30$		$h_s/300$

Symbol:

h - height of the multi-storey building, taken as the space from the foundation surface to the axis of roof floor supporting bar

h_s - height of the storey of one-storey house, taken as the space from the foundation surface to the lower surface of the truss. In the multi-storey buildings: for the lower floor: taken as the space from the foundation surface to the axis of roof floor supporting bar: for the remains, taken as spaces among axes of each storey bar.

Note 1: For the immediate values h_s (according to item 3), the limit horizontal transformation should be determined by the linear interpolate

Note 2**:** For the uppermost storey of the multi-storey building with design of using the one – storey roof floor member, the limit horizontal transformation should be determined the same as for the one – storey house. In which the height of the uppermost storey h_s is taken from the axis of the floor beam to the lower surface of the truss structure.

Note 3: Soft connections consist of the walls, or wall separating with frame which do not prevent the movement of frame (do not transmit into the walls and internal force preventing wall so that can cause damages for the constructive parts); Hard connections consist of connections that prevent the reciprocal movement of the wall frame or separating wall.

Note 4: For the one -storey house with hanging wall (as well as in the absence of the roof floor's hard piece) and the storey of the multi-storey building, limit horizontal transformation is allowed to increase by 30% (but not more than $h_s/150$).

C.5.5. Limit deflection according to the horizontal direction according to the technological requirements of the conveyor load supports due to the wind load, is taken equal to h/250, in which h is the height from the foundation surface to the under surface of frame or beam.

C.5.6. Limit deflection according to the horizontal direction of the frame house pillars due to the impact of temperature, climate and the depression is taken as:

h/150 – when the wall and separating wall of brick, gypsum concrete, reinforcement concrete or the built-up panel

h/200 – when the walls covered with the natural stone, made from the ceramic block or glass in which h is the story's height, for the one -storey house with bridge crane, h – is the height from the foundation surface to the lower surface of the crane beam.

Then the impact of temperature should be taken into account not including the changes of day and night air temperature and the difference of temperature due to the sun radiation.

To determine the deflection according to the horizontal direction due to the impact of temperature, climate, depression, their values should not be plus with the deflection due to the wind load and the declination of foundation.

C.6. The swelling of the members of the floor structure between the storey due to the pre-compression force.

C.6.1. The limit swelling of the floor members between the storey according to the constructive requirements, is taken as 15 mm when $l \leq 3$ m and 40 mm when $l \leq 12$ m (for the immediate l value, the limit swelling is determined by the linear interpolate).

C.6.2. The swelling f should be determined due to pre-compression force, itself weight of the floor members and the weight of the floor pavement.

C.7. Method of determination of the deflection and transformation (for reference)

C.7.1. When determining the deflection and transformation, it is necessary to take into account all the substantial elements that affect their values (non-elastic deformation of materials , the formation of cracks, including the diagram of deformation, adjacent structures, softness of the joints and base).

When there are sufficient basis, it is likely not to take into account some certain elements or the approximate method.

C.7.2. For the structures using the creep materials, it is necessary to take into account the increase of deflection in accordance with the period of time. When limiting the deflection according to the psycho physiological requirements, only take into account the short-term creep that appears right after uploading, and according to the technological and constructive requirements (except for the calculation that include the wind load), aesthetic and psychological requirements, take into account the whole creep.

C.7.3. When determining the deflection of the pillar of one-storey house and viaduct due to the horizontal load of the bridge crane, it is necessary to select the calculating diagram of pillar, taking into account the connecting conditions with the suppose that:

- There is no horizontal movement in the indoor pillar and leading bridges at the height of uppermost supports (if the roof floor does not form the hard piece in the horizontal plane, taking into account the softness according to the horizontal direction of this support);

- Pillars in the outdoor leading bridges are considered to be the cantilevers.

C.7.4. When the in houses and buildings with the technological and transporting equipments that cause the oscillation for constructive members as well as the other sources of oscillation, the limit value of the oscillating transformation, oscillating speed and the oscillating acceleration should be taken according to the requirement on oscillation at work and houses in the relating standards. When there are equipments and devices with high accuracy which are sensitive to the oscillation of structures on which they are placed, the limit value of the oscillating transformation, oscillating speed and the oscillating acceleration should be determined with the specific technical conditions.

C.7.5. *Calculation situation** in which it is necessary to determine the deflection, transformation and relative load shall be selected depending on the fact that the calculation is done according to what kind of requirements.

If the calculation is done according to the technological requirements, the calculation situation must be corresponding to the action of load which affects the working of technological equipment.

If the calculation is done according to the constructive requirements, the calculation situation must be corresponding to the action of load which causes damages to adjacent structures due to the too great swelling and transformation.

If the calculation is done according to the psycho physiological requirements, the calculation situation must be corresponding to the states relating to the oscillation of structures. The design must take into account the load affecting the oscillation (of structures) that meets the requirements in the item C.7.4. and of this standard.

If the calculation is done according to the aesthetic and psychological requirements, the calculation situation must be corresponding to the action of long-term and frequent load.

For the floor and roof structures designed with the initial swelling according to the aesthetic and psychological requirements, the determined deflection according to the longitudinal direction shall be minus one quantity which is equal to that initial swelling.

*Note: * Calculation situation*: the set of conditions to determine the calculating requirements for structures mentioned in the calculation.

Calculation situation is characterized by the calculating diagram of structure, types of loads, values of coefficients, working conditions and the confident coefficient, number of limit states considered in that calculation situation.

C.7.6. The deflection of floor and roof members is limited according to the constructive requirements, not more than the distance (clearance) between the lower side of those members and the upper side of the glass partition, window frame, and door under the structural members.

Clearances between the lower sides of the floor and roof members between the storey and the upper side of the glass partitions under those members do not exceed 40 mm. In cases of implementing above mentioned requirements, we have to increase the hardness of the floor and roof floor, prevent from increasing that hardness by the constructive measures (for example not place the separating walls under the bent beam but beside it).

C.7.7. In cases that there are structural separating walls between walls (in fact, with the same height with the wall), the value l in the item 2a of table C.1. should be taken equal to the distance between the inside faces of the structural walls (or pillar) and the separating walls (or between the inside faces of the separating walls as in the figure C.1).

C.7.8. The deflection of truss structures when there is the railway of bridge crane, (Table C.1, item 2d) should be taken as the difference between the deflection f_1 and f_2 if adjacent truss structure (figure C.2).

C.7.9. The transformation according to the horizontal direction of frame shall be determined in the plane of wall and separating wall in which their integrity is ensured.

In the system of the connecting frames of the multi-storey building with the height of over 40 m, the declination in pieces of storey adjacent to the hard wall shall be taken as $f_1 / h_s + f_2 / l$ (Fig. C.3), not more than (Table C.4): - l/300 for the item 2; - l/500 for the item 2a; - l/700 for the item 2b;

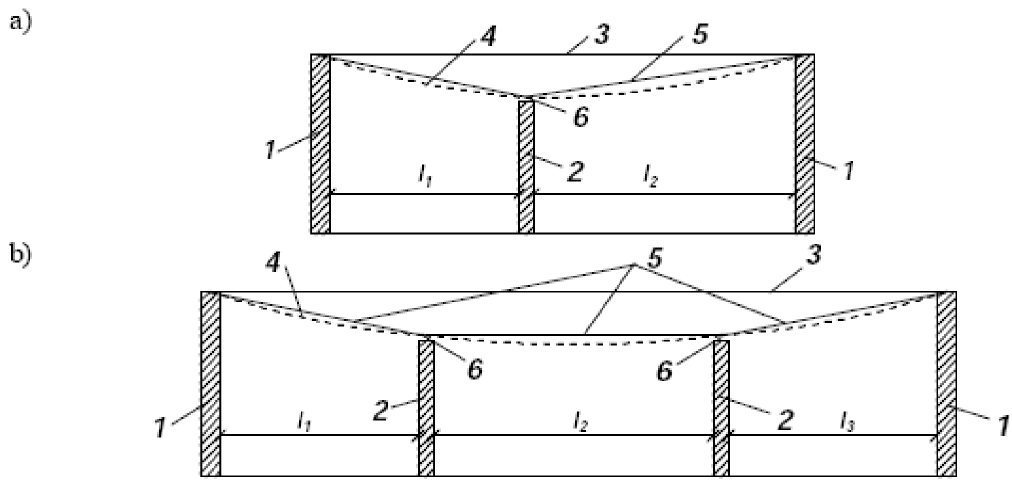


Figure C.1 – Diagram determining the values l, l_1, l_2, l_3, when there are the separating walls between structural walls

a) with one separating wall; b) with two separating walls; 1- structural wall (or pillar); 2- separating wall; 3 – floor between storeys (or roof floor) before being subjected to the load; 4- floor between storeys (or roof floor) under the load; 5 – milestone straight line to calculate the deflection; 6- clearance

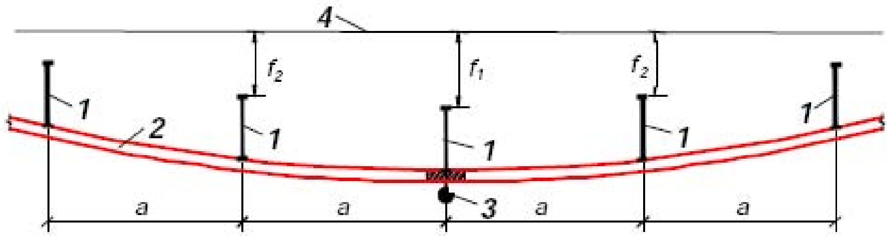


Figure C2- Diagram for calculating the deflection of the structure due to the rafter when having rail of the suspension crane

1 – structure due to rafter ; 2 – beam; 3 – suspension crane; 4 – the initial position of the structure due to rafter; f_1 –deflection of the most load bearing structure due to rafter; f_2 – deflection of the structure due to rafter near the most load bearing structure due to rafter

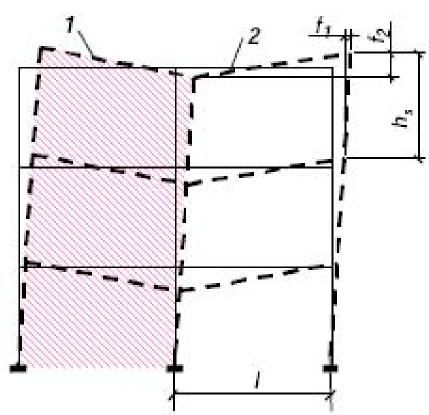


Figure C3 - Diagram of the deflection of the raft 2 within the scope of stages, contiguous to the hard partition 1 in the braced box frame building (continuous line for showing the initial diagram of the frame before bearing load)

Annex D
Working condition groups of the crane and suspension crane

Crane	Working condition groups	Condition of use
– Manual operation (all types) – With transmission suspended tackle including suspension clamp. – Crane with load bearing vehicles in winch form including suspension clamp.	1K–3K	– Any – Used for repair, transportation with limited strength. – Used for machinery rooms of the thermal stations, for assembly, transportation with limited strength.
– Crane with load bearing vehicles in winch form including suspension clamp. – Two cable bucket crane, magnet bucket crane – Magnet crane	4K–6K	– Used for transportation with average strength; for technology works in the mechanical workshops, storehouses of finished products of building materials factories; for storehouses of consumption metal products. – Mixed stores, for works with different load types. – For semi finished stores with different load types.
– Crane for forging, tempering, casting, – Two cable bucket crane, magnet bucket crane – Crane with load bearing vehicles in winch form including suspension clamp.	7K	– In the workshops of metallurgy factory, stores of heap materials, homogeneous scrap iron (working at one or two shifts). – Technology cranes working all days and nights.
– Horizontal, trough bucket crane, trough charging crane, crane for supporting cast steel billets, crane for smashing, high furnace crane. – Magnet crane – Two cable bucket crane, magnet bucket crane	8K	– In the workshops of metallurgy factory, – In the workshops and stores of metallurgy factory, stores of big metals with homogeneous products. – Stores of heap materials and homogeneous scrap iron (working all days and nights.)

Annex E

Quantities used for caculation according to durability

Table E.1. Coefficiences ξ, ζ, α_m

ξ	ζ	α_m	ξ	ζ	α_m	ξ	ζ	α_m
0.01	0.995	0.010	0.26	0.870	0.226	0.51	0.745	0.380
0.02	0.990	0.020	0.27	0.865	0.234	0.52	0.740	0.385
0.03	0.985	0.030	0.28	0.860	0.241	0.53	0.735	0.390
0.04	0.980	0.039	0.29	0.855	0.243	0.54	0.730	0.394
0.05	0.975	0.049	0.30	0.850	0.255	0.55	0.725	0.399
0.06	0.970	0.058	0.31	0.845	0.262	0.56	0.720	0.403
0.07	0.965	0.068	0.32	0.840	0.269	0.57	0.715	0.407
0.08	0.960	0.077	0.33	0.835	0.276	0.58	0.710	0.412
0.09	0.955	0.086	0.34	0.830	0.282	0.59	0.705	0.416
0.10	0.950	0.095	0.35	0.825	0.289	0.60	0.700	0.420
0.11	0.945	0.104	0.36	0.820	0.295	0.62	0.690	0.428
0.12	0.940	0.113	0.37	0.815	0.302	0.64	0.680	0.435
0.13	0.935	0.122	0.38	0.810	0.308	0.66	0.670	0.442
0.14	0.930	0.130	0.39	0.805	0.314	0.68	0.660	0.449
0.15	0.925	0.139	0.40	0.800	0.320	0.70	0.650	0.455
0.16	0.920	0.147	0.41	0.795	0.326	0.72	0.640	0.461
0.17	0.915	0.156	0.42	0.790	0.332	0.74	0.630	0.466
0.18	0.910	0.164	0.43	0.785	0.338	0.76	0.620	0.471
0.19	0.905	0.172	0.44	0.780	0.343	0.78	0.610	0.476
0.20	0.900	0.180	0.45	0.775	0.349	0.80	0.600	0.480
0.21	0.895	0.188	0.46	0.770	0.354	0.85	0.575	0.489
0.22	0.890	0.196	0.47	0.765	0.360	0.90	0.550	0.495
0.23	0.885	0.204	0.48	0.760	0.365	0.95	0.525	0.499
0.24	0.880	0.211	0.49	0.755	0.370	1.00	0.500	0.500
0.25	0.875	0.219	0.50	0.750	0.375	—	—	—

Table E.2. ω, ξ_R, α_R **values to components made from heavy concrete**

Working condition factor of the concrete γ_{b2}	Tensile reinforcement group	Symbol	Compressive durability grade of concrete										
			B12.5	B15	B20	B25	B30	B35	B40	B45	B50	B55	B60
0.9	Any	ω	0.796	0.789	0.767	0.746	0.728	0.710	0.692	0.670	0.652	0.634	0.612
	CIII, A-III (Φ10–40) and Bp-I (Φ4; 5)	ξ_R	0.662	0.654	0.628	0.604	0.583	0.564	0.544	0.521	0.503	0.484	0.463
		α_R	0.443	0.440	0.431	0.421	0.413	0.405	0.396	0.385	0.376	0.367	0.356
	CII, A-II	ξ_R	0.689	0.681	0.656	0.632	0.612	0.592	0.573	0.550	0.531	0.512	0.491
		α_R	0.452	0.449	0.441	0.432	0.425	0.417	0.409	0.399	0.390	0.381	0.370
	CI, A-I	ξ_R	0.708	0.700	0.675	0.651	0.631	0.612	0.593	0.570	0.551	0.532	0.511
		α_R	0.457	0.455	0.447	0.439	0.432	0.425	0.417	0.407	0.399	0.391	0.380
1.0	Any	ω	0.790	0.782	0.758	0.734	0.714	0.694	0.674	0.650	0.630	0.610	0.586
	CIII, A-III (Φ 10–40) and Bp-I (Φ4.5)	ξ_R	0.628	0.619	0.590	0.563	0.541	0.519	0.498	0.473	0.453	0.434	0.411
		α_R	0.431	0.427	0.416	0.405	0.395	0.384	0.374	0.361	0.351	0.340	0.326
	CII, A-II	ξ_R	0.660	0.650	0.623	0.595	0.573	0.552	0.530	0.505	0.485	0.465	0.442
		α_R	0.442	0.439	0.429	0.418	0.409	0.399	0.390	0.378	0.367	0.357	0.344
	CI, A-I	ξ_R	0.682	0.673	0.645	0.618	0.596	0.575	0.553	0.528	0.508	0.488	0.464
		α_R	0.449	0.446	0.437	0.427	0.419	0.410	0.400	0.389	0.379	0.369	0.356
1.1	Any	ω	0.784	0.775	0.749	0.722	0.700	0.808	0.810	0.630	0.608	0.586	0.560
	CIII, A-III (Φ 10–40) and Bp-I (Φ4.5)	ξ_R	0.621	0.611	0.580	0.550	0.526	0.650	0.652	0.453	0.432	0.411	0.386
		α_R	0.428	0.424	0.412	0.399	0.388	0.439	0.440	0.351	0.339	0.326	0.312
	CII, A-II	ξ_R	0.653	0.642	0.612	0.582	0.558	0.681	0.683	0.485	0.463	0.442	0.416
		α_R	0.440	0.436	0.425	0.413	0.402	0.449	0.450	0.367	0.356	0.344	0.330
	CI, A-I	ξ_R	0.675	0.665	0.635	0.605	0.582	0.703	0.705	0.508	0.486	0.464	0.438
		α_R	0.447	0.444	0.433	0.422	0.412	0.456	0.456	0.379	0.368	0.356	0.342

$\omega = 0.85 - 0.008R_b$; $\xi_R = \dfrac{\omega}{1 + \dfrac{R_s}{\sigma_{sc,u}}\left(1 - \dfrac{\omega}{1{,}1}\right)}$; $\alpha_R = \xi_R(1 - 0.5\xi_R)$.

Note: The values ω, ξ_R and α_R given in the table do not concern the factor γ_{bi} given in table 14.

Annex F

(Normative)

Deflection of simple beams

Deflection of live simple beams according to cantilever diagram or liberally arrange is defined as follows:

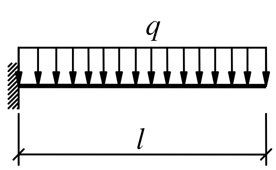
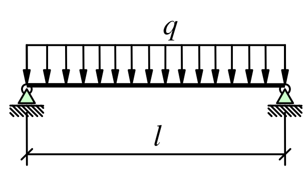
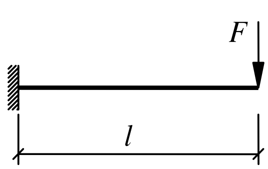
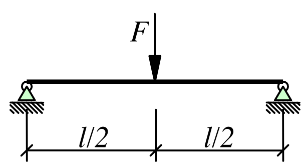
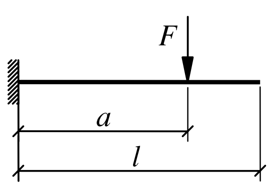
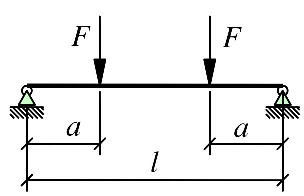
$f_m = (1/r)_m \beta l^2$ (F.1)

Where:

$(1/r)_m$ defined according to formula (158) if no crack in the tensile area appears and (173) if appearing this crack;

β- is load characteristic factor, taken in accordance with Table F.1;

Table F.1; The factor β

Diagram	β	Diagram	β
	$\frac{1}{4}$		$\frac{5}{48}$
	$\frac{1}{3}$		$\frac{1}{12}$
	$\frac{a}{6l}\left(3-\frac{a}{l}\right)$		$\frac{1}{8}-\frac{a^2}{6l^2}$

Note: If the beam is under the effect of many types of load simultaneously according to table F.1, β shall be defined as follows:

$$\beta = \frac{\beta_1 M_1 + \beta_2 M_2 + ... + \beta_n M_n}{M_1 + M_2 + ... + M_n} \quad \text{(F.2)}$$

Where:

β_1 and M_1, β_2 and M_2, …, β_n and M_n is the factor β and the maximum bending moment for each load diagram, correspondingly. In this case, in formula F.1, $(1/r)_m$ defined correspondingly to bending moment value M is the total of maximum bending moment values for each load diagram.

Annex G: Table of conversion unit into SI system

Quantity	The old technical unit	SI system		Conversion relation
		Name	Symbol	
Force	kG T (ton)	Newton Kilo Newton Meganewton	N kN MN	1 kG = 9.81 N ≈ 10 N 1 kN = 1000 N 1 T = 9.81 kN ≈ 10 N 1 MN = 1 000 000 N
Moment	kGm Tm	Newton meter Kilonewton meter	Nm kNm	1 kGm = 9.81 Nm ≈ 10 N 1 Tm = 9.81 kNm ≈ 10 kNm
Pressure; Strength; Elastic moment	kG/mm^2 kG/cm^2 T/m^2	$Newton/mm^2$ Pascal Megapascal	N/mm^2 Pa MPa	1 Pa = $1N/m^2$ ≈ 0.1 kG/m^2 1 kPa = 1000 Pa = 1000 N/m^2 = 100 kG/m^2 1 MPa = 1 000 000 Pa = 1000 kPa ≈ 100 000 kG/m^2 = 10 kG/cm^2 1 MPa = 1 N/mm^2 1 kG/mm^2 = 9.81 N/mm^2 1 kG/mm^2 = 9.81 x $10^4 N/m^2$ ≈ 0.1 MN/m^2 = 0.1 MPa 1 kG/m^2 = 9.81 N/m^2 = 9.81 Pa ≈ 10 N/m^2 = $1daN/m^2$