CONCRETE

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1. CONCRETE COMPOSITION ASSESSMENT

Generalities

Concrete is an artificial stone which is obtained after hardening the homogenous mixtures of cement, water, aggregates and sometime admixture and/or additive (to modify the fresh and hardened concrete property).

The concrete composition must be established in order to assure the resistance and durability of building elements, by using less cement dosage.

The concrete composition is established by the next parameters:

- concrete class which is indicated by the designer;
- cement type;
- additive type according to the requirements from the project;
- concrete consistency according to the element type which is to be realised;

- impermeability, freeze proof ness, maximum water/ cement ratio **W/C** and the minimum cement dosage according to the minimum requirements for durability assurance;
- aggregate grading zones, aggregate grading and maximum granule shape according to the shape and dimension elements and the distance between reinforcements.

The composition is expressed in dosages which represent the materials' quantities necessary for **1 m^3** of concrete: cement, water, aggregates, admixture and/or additive.

Concrete consistency is established according to the element type shown in table 1.

Table 1. *The concrete consistency versus element type*

Concrete element type	**Concrete Consistency**
Base foundations from ordinary concrete, low reinforced concrete and massive elements	S_2 or S_3
Base foundations from reinforced concrete, columns, beams, structural walls	S_3 or S_4
Base foundations from reinforced concrete, columns, beams, structural walls realised with fluid concrete;	S_4
Elements with dense steel reinforcement or thin elements	S_4 or S_5
Elements realised with very fluid concrete	S_5

1.1. Concrete Composition Assessment In Accordance With NE 012-2007

The concrete composition established contains the next programme steps:

Programme step I: The preliminary dosages establishing

a) The preliminary dosage of water W' is obtained from table 2 according to concrete class, consistency, maximum granule size and aggregate type for preliminary tests.

Table 2. *The water as a rough guide for mixture*

Concrete class	**Water quantity W' (ℓ/m³), For 0…31 mm river aggregate and consistency:**			
	S2	**S3**	**S4**	**S5**
< C 8/10	160	170	-	-
C 8/10…C20 /25	170	185	200	220
≥ C 25/30	185	200	215	230

The following water corrections can be necessary in the next situations:

- 10-20% decrease for additive use;
- 20% increase for using 0 ... 8 mm aggregate;
- 10% increase for using 0 ... 16 mm aggregate;
- 10% decrease for using 0 ... 63 mm aggregate;
- 10% increase for broken stone used.

b) The preliminary dosage of cement C' is established by:

$$C' = \frac{W'}{W/C} \qquad (kg/m^3) \qquad (1)$$

where: W' - the initial water quantity which is established at a) paragraph;

W/C - the water/cement ratio to achieve the resistance and durability requirements.

The water-cement ratio (W/C) is established from the table 3 according to the concrete class, cement class, concrete homogenous grade and aggregate type.

Table 3. *W/C maximum values for different concrete classes*

Concrete class	**Cement class / Concrete homogenous grade**								
	32.5			**42.5**			**52.5**		
	I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
C 8/10	0.80	0,75	0.70						
C 12/15	0.70	0.65	0.60						
C 16/20	0.60	0,55	0.50	0.70	0.65	0.60			
C18/22.5	0.58	0.53	0.48	0.67	0.62	0.57			
C 20/25	0.55	0.50	0.45	0.65	0.60	0.55			
C 25/30	0.50	0.45	0.40	0.60	0.55	0.50	0.65	0.60	0.55
C 28/35*	0.45	0.40	0.35	0.55	0.50	0.45	0.60	0.55	0.50
C 30/37				0.52	0.47	0.42	0.58	0.53	0.48
C 32/40*				0.50	0.45	0.40	0.55	0.50	0.45
C 35/45				0.45	0.40	0.35	0.52	0.47	0.42
C 40/50							0.50	0.45	0.40
C 45/55							0.47	0.42	0.37
C 50/60							0.45	0.40	0.35
Notes: * = concrete classes which are not in the European Norms; - If quarry aggregates are used, then the values from the table are increased with 10%.									

The concrete homogenous grade (I, II or III) is shown in table 3, which results from the statistical information from concreting plant; when there aren't any preliminary dates, III concrete homogenous grade is used.

c) The preliminary dosage of dry aggregate A'_g, is obtained by:

$$A'_g = \rho_{ag}\left(1000 - \frac{C'}{\rho_c} - W' - P\right) \qquad (kg/m^3) \qquad (2)$$

where:

- ρ_c =3.0 kg/dm^3 is cement actual density;
- ρ_{ag} =2.7 kg/dm^3 is actual density of river and granite rock aggregate (siliceous);
- W', C' - water and cement preliminary dosages which were established at **a)** and **b)** paragraphs;
- P = 20 dm^3/m^3 or 2% is the air volume from the concrete which results from the concrete admixing.

d) Apparent density of green concrete ρ'_{gc} is established with the relation:

$$\rho'_{gc} = W' + C' + A'_g \qquad (kg/m^3) \qquad (3)$$

The aggregate grading is chosen in correlation with data from table 4 according to the workability and cement preliminary dosage value.

Table 4. *Aggregate grading zones prescript*

Concrete consistency by cone slump	**Preliminary cement dosage (ℓ/m³)**			
	<200	**200 - 300**	**300 - 400**	**>400**
S_2	I	I (II)	II (III)	III
S_3	I	I (II)	II (III)	III
S_4, S_5	-	I	I (II)	II (III)
Obs.: Grading zones presented in parentheses can be chosen when the concrete mixture doesn't have segregation tendency.				

The proportions between the sorts' aggregates and their quantities are establishing in table 5, so the grading curve of the final aggregate could be into the grading zone which was prescript.

Table 5 *The aggregates grading limits*

Aggregate	**Zone**	**Limit**	**% of mass sifting through sieve or riddle:**					
			0.2	**1**	**4**	**8**	**16**	**31**
0…8	**-**	min	3	25	54	95		
		max	12	40	70	100		
0…16	I	min	3	35	51	71	95	
		max	11	45	60	80	100	
	II	min	2	25	41	61	95	
		max	8	35	50	70	100	
	III	min	1	15	30	50	95	
		max	6	25	40	60	100	
0…31	I	min	3	31	41	61	81	95
		max	10	40	50	70	90	100
	II	min	2	21	31	51	71	95
		max	7	30	40	60	80	100
	III	min	1	10	20	40	60	95
		max	5	20	30	50	70	100

$$A'_{g\ 0/31} = A'_{g\ 0/4} + A'_{g\ 4/8} + A'_{g\ 8/16} + A'_{g\ 16/31}$$

e) Preliminary dosage of admixture (additive) A'_d: is established according to the cement quantity and for each admixture type:

$$A'_d = f(C') \qquad (l/m^3) \qquad (4)$$

where: C' - the preliminary dosage of cement established to paragraph **b)**, in kg/m^3.

Programme step II: The composition test

To establish the base mixture composition, the next steps are followed:

- a minimum 30 λ of preliminary concrete mixture is prepared with the dosages which were established in the program step I;
- the additive is mixed with a small quantity of water and introduced gradually into the mixture;
- the last water is introduced into the mixture until the purposed concretes' consistency is obtained (which is determined by slump method);
- final water dosage **W** is established;
- the apparent density of green concrete ρ_{gc}, in kg/m^3 is determined (by weighting of steel mould fill with concrete);
- final cement dosage **C** is calculated by:

$$C = \frac{W}{w/C} \qquad (kg/m^3) \qquad (5)$$

where: W - final water dosage, in ℓ/m^3;

W/C - the water/cement ratio value from table 3.

- the total aggregate dosage $\mathbf{A_g}$ is recalculated by the relation:

$$A_g = \frac{\rho'_{gc} + \rho_{gc}}{2} - W - C \qquad (kg/m^3) \qquad (6)$$

where: ρ'_{gc} - apparent density of green concrete, calculated with relation 3, in kg/m^3;

ρ_{gc} - apparent density of green concrete determinates in-situ, in kg/m^3;

W - final water dosage, in l/m^3;

C - final cement dosage, in kg/m^3.

Programme step III: The concrete composition definitive

To check the mechanical strengths, 3 concrete mixtures by 30 ℓ minimum each, are prepared with the next compositions:

a) **first is base composition**, with **W, C, $\mathbf{A_g}$** established in the programme step III (W, C, A_g);

b) second supplementary composition (W, C+7%, A_g) with a **7%** cement dosage **addition** (with 20 kg/m^3 minimum) towards base composition; **W** and $\mathbf{A_g}$ of base composition is kept;

c) third supplementary composition (W, C-7%, A_g) with a **7%** cement dosage **decrease** (with 20 kg/m^3 minimum) towards base composition; **W** and $\mathbf{A_g}$ of base composition is kept.

Minimum 4 samples for each mixture type must be made, resulting in 12 samples. The making, keeping and testing will be made in accordance with the standards norms.

Will be chosen like final composition, the composition, that has the value of compressive strength at 28 days, equal or grater then compressive strength value presented in table 2.6 (in accordance with norms). The values in the table are for II concrete homogenous grade; for I or III concrete homogenous grade the value from table 6 will be decreased or increased with the next Δ value:

- for C8/10-C20/25 concrete: Δ=2.5 N/mm^2-cylinder and Δ=3.0 N/mm^2 - cube;
- for C28/35-C35/45 concrete: Δ=3.0 N/mm^2- cylinder and Δ=4.0 N/mm^2 - cube;
- for C40/50-C50/60 concrete: Δ=4.0 N/mm^2- cylinder and Δ=5.0 N/mm^2 - cube.

Table 6 *Minimum compressive strengths at 28 days for preliminary tests (NE 012-99)*

Concrete class	preliminary f_c, N/mm^2	
	Cylinder	Cube
C 8/10	14.5	18.0
C 12/15	19.0	23.5
C 16/20	23.0	29.0
C 18/22.5	26.0	32.0
C 20/25	29.0	36.0
C 25/30	33.5	42.0
C 28/35	37.5	47.0
C 30/37	38.5	48.0
C 32/40	41.0	51.5
C 35/45	45.0	56.5
C 40/50	50.0	62.5
C 45/55	54.0	67.5
C 50/60	58.0	73.0
Obs.: The values presented are valid for II concrete homogenous grade		

Example: for **C 20/25** concrete class (put in columns, beams, etc), realised with portland cement with slag **CEM II/A-S32.5R** type, river aggregate with $\mathbf{d_{max}}$ **=16 mm** (0/4; 4/8; 8/16 sorts is used) and additive. The fresh (green) concrete consistency established by slump method is $\mathbf{S_3}$ and **III** homogenous grade. It is known: ρ_{ag} **= 2.7 kg/dm³** (for aggregate),
ρ_c **= 3.0 kg/dm³** (for cement), **P = 20 dm³/m³** (air volume).

Concrete code: **C 20/25** - $\mathbf{S_3}$ - **CEM II/A-S32.5R/0...16**

Programme step I: The preliminary dosages establish

a) The preliminary dosage of water W' (from tab. 2):

$$W' = 200 \times 1.10 \times 0{,}80 = 176\ \ell/m^3$$

1.10 = the correction index by using an aggregate with d_{max} =16 mm
0.80 = the correction index by using an additive

b) The preliminary dosage of cement C':

$$C' = \frac{W'}{W/C} = \frac{176}{0.5} \approx 391\ (kg/m^3)$$

W/C = 0.45 = water/cement ratio (from tab. 3)

c) The preliminary dosage of dry aggregate A'$_g$, is obtained from:

$$A'_g = \rho_{ag}\left(1000 - \frac{C'}{\rho_c} - W' - P\right) = 2.7\left(1000 - \frac{391}{3} - 176 - 20\right) \approx 1819\ \ kg/m^3$$

d) Apparent density of green concrete ρ'_{gc} is established by:

$$\rho'_{gc} = W' + C' + A'_g = 176 + 391 + 1819 = 2386 \ \text{kg/m}^3$$

e) Preliminary dosage of additive A'_d

$A'_d = f(C') = 0.7\% \times 391 = 1.92\ \ell$

An additive like polycarboxylether (plastics) can be used usually at 0.7% percent.

e) Total aggregate grading established

According to the consistency (T_3/T_4) and cement dosage ($C' = 391\ \text{kg/m}^3$) in the table 4, **II grading zone** is chosen.

The limits of II grading zone for aggregate with d_{max} =16 mm are established in table 7:

Table 7

Table 7 *Limits of the aggregate grading*

Zone II of aggregate grading		**% of sifting on sieve (riddle):**				
		0.2	**1**	**4**	**8**	**16**
Limits	Minimum	2	25	41	61	95
	Maximum	8	35	50	70	100
Aggregate chosen		5	30	45	65	100

$$A'_{g\ 0/16} = A'_{g\ 0/4} + A'_{g\ 4/8} + A'_{g\ 8/16}$$

$A'_{g\ 0/4}$ = 45% - 0% = 45% = 0.45 x 1819 ≈ 818.5 kg/m^3

$A'_{g\ 4/8}$ = 65% - 45% = 20% = 0.20 x 1819 ≈ 363.8 kg/m^3

$A'_{g\ 8/16}$ = 100% - 65% = 35% = 0.35 x 1819 ≈ 636.7 kg/m^3

2. DETERMINATIONS ON FRESH CONCRETE

Generalities

The concrete' state beginning with its components mixture until starting the setting time of the cement is called fresh concrete.

In this work on fresh concrete, made with heavy or light aggregates, the following determinations are done (according to STAS 1759-1988): apparent density and workability. Determination of fresh concrete's characteristics must be done at maximum 10 minutes since it was prepared.

2.1. Determination of Apparent Volume Mass

Determination of apparent volume mass (density) is based on weighting a mass of fresh concrete and dividing it to its volume in a compacted state.

For this determinations the following are necessary: a weighting balance (for max. 100 kg); a tight metallic vessel, which has a prolongation and its form is a cubic or a cylindrical one, the walls of the vessel are smooth and stiff, the vessel is made by a sheet of min. 2 mm thick, a trowel; a metallic line; a laboratory vibrating table (for compaction).

The technology for mass determination of the fresh concrete sample is the following:

- for a vessel with known volume **V** the mass is determined, **m**;
- the prolongation is then put to the vessel and both are gently wetted in their interior with water by help of a wet cloth;
- the fresh concrete is put into the vessel until the superior edge of the prolongation;

- the concrete is vibrated until no more air bubbles are observed on its surface;
- the prolongation is taken away and the surface of concrete it is levelled by use of the metallic line;
- by weighting is determined the mass $\mathbf{m_1}$ of the filled vessel with concrete.

The apparent density of the fresh concrete is computed using the expression:

$$\rho_a = \frac{m_1 - m}{V} \quad (kg/m^3) \qquad (7)$$

The result will be the arithmetical mean of two determinations.

2.2. Workability Determination

The workability is the concrete's property not to present segregation at its transport and manipulation, and also to present a good cohesion and to fulfil the case in which it is poured. This it is appreciated by concrete consistency which can be determined by: **Slump method** used for all concretes which has aggregates of max. 120 mm.

This method is not recommended for concretes with low workability.

Slump method

It is based on measuring the settle of the fresh concrete under its proper weight.

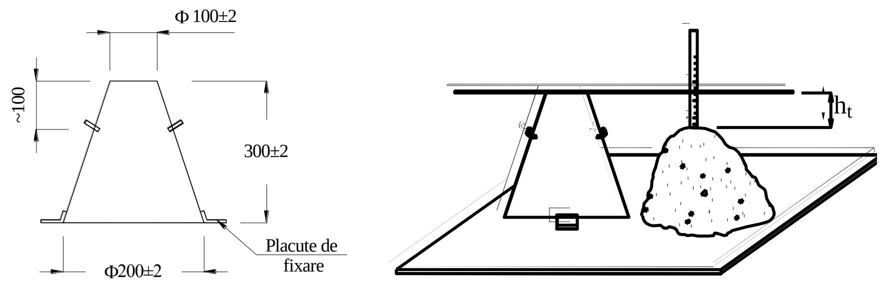
For determination are used:

- one tronconic vessel made of galvanised sheet of 2 mm thick, such as presented in fig. 1.a, provided with a prolongation;
- a steel rod (ϕ=16 mm, ℓ=600 mm) with rounded ends;
- one metallic line (ℓ=600 mm), a trowel;

- a scaled line (ℓ=500 mm).

The determination will be done such as presented bellow:

- the tronconic vessel is filled with concrete in three successive layers, each layer corresponding to one third of the vessel's height;
- in each layer 25 stitches by use of the metallic rod are done; the rod must gently penetrate the anterior layer of concrete (for superior layer the prolongation is added to the vessel);



a) b)

Fig. 1

- the prolongation is taken away and the surface of concrete it is levelled by use of the metallic line; during the filling and compaction, the tronconic vessel is fixed to the plane surface on which it was placed; this is done by help of its fixing plates;
- the tronconic vessel is raised vertically in 5…10 seconds, without making any lateral movements or spins; all these operations must not exceed 150 seconds;
- the difference ($\mathbf{h_t}$) between the tronconic vessel's height and the most raised point of fresh slumped concrete is measured (fig. 1.b).

The value $\mathbf{h_t}$ expresses the concrete slump.

The result is considered the arithmetical mean of two determinations done at a time interval of maximum 10 minutes.

The fresh concrete classification according to classes of consistency is presented in the table (acc. NE 012-2007) 8.

Table 8 *The concretes classes of consistency - Slump method*

Class	**S_1**	**S_2**	**S_3**	**S_4**	**S_5**
Slump [mm]	10-40	50-90	100-150	160-210	≥220

3. NON-DESTRUCTIVE TESTING ON HARDENED CONCRETE

Generalities

Considerable advantages can be gained using non-destructive methods of testing. The various methods offer speed, relative low cost and lack of damage when compared to more conventional method of test which requires the removal of samples for subsequent testing. A wide range of properties can be investigated including: strength, density, surface hardness surface absorption, location of reinforcement and many others. Most used non-destructive testing of materials are: surface methods (test hummer, indentation hardness, penetration, pull out test), acoustical methods (pulse velocity measurement, resonant frequency, method of acoustic emission); radiographic methods based on penetrating radiation (X and γ ray, neutrons); electromagnetic measurement (convert meter method, micro ray attenuation method); other methods (method of fluorescent ink, photo elasticity method, half-cell corrosion test kit etc).

3.1. The Compressive Strength Evaluation of Concrete by Combined Method

The Combined Method uses the values which are obtained with ultrasonic device and test hummer. With these data the compressive strength is obtained using the chart from figure 2 or table 10.

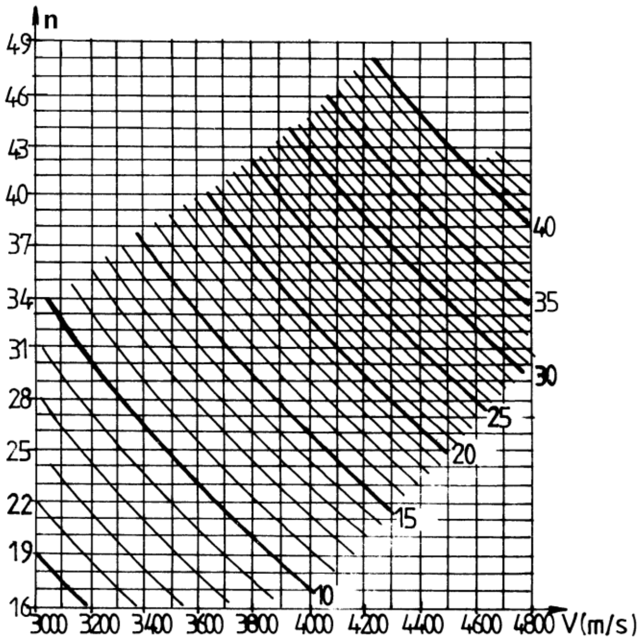


Fig. 2

Test hummer

The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface which it strikes. Various spring – loaded steel rebound hammers are available for a variety of concrete type. Principle applications are the determination of concrete uniformity; strength and in situ strength estimations (figure 3 and 4). The test is often used in combination with ultrasonic pulse velocity measurement.

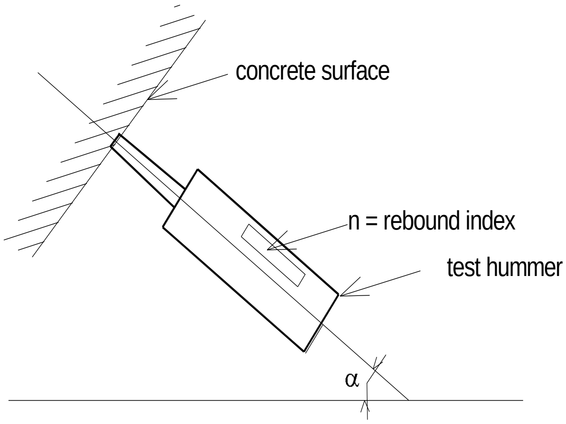


Fig. 3

Pulse velocity measurement

The basic principle of this method of testing is that the velocity of an ultra sonic pulse through material (concrete) is related to its density and elastic properties. The unit generates slow frequency pulses and measures the time taken for them to pass between two transducers placed at two points on the concrete being tested (figure 4 and 5). The great advantage of this method over all other non-destructive tests is that the pulse passes through the complete thickness of the concrete so that significant defects can be detected. Main uses of this method include: the measurement of concrete humidity; the presence or absence of voids, cracks and other imperfections; deterioration of the concrete due to the action of fire, frost or chemical attack, measurement of layer thickness and elastic modulus etc.

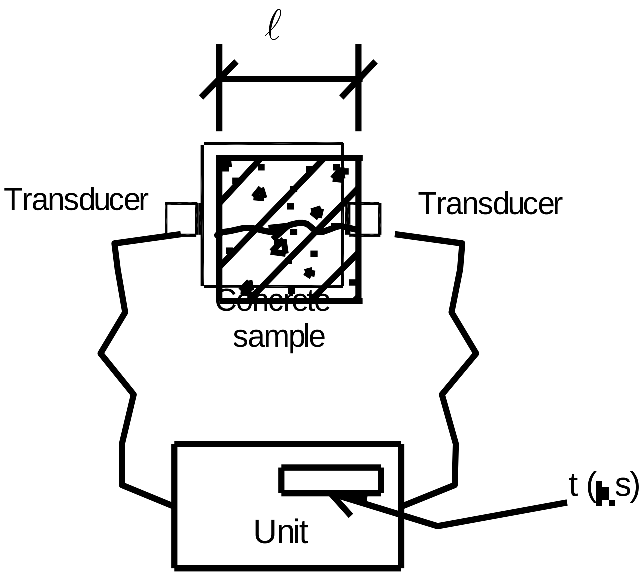


Fig. 4

The compression strength concrete determination by non-destructive combined method needs the following dates:

a) v - **velocity of ultrasound** which are calculate by:

$$v_L = \frac{l}{t} \qquad \text{(m/s)} \qquad (8)$$

where:

l = the distance between transducers, in m;

t = time of impulse propagation through concrete, in s.

b) n – rebound index, which are determined with test hummer.

The reference compressive strength concrete (f_c^{ref}) is determined by:

$$f_c^{ref} = F(v; n) \qquad (9)$$

where: v - ultrasound velocity, in m/s;

n - rebound index

With these data and table 1 the reference compressive strength concrete (f_c^{ref}) can be establish.

The compressive strength concrete (f_c) can be calculated by:

$$f_c = f_c^{ref} \times C_t \qquad (10)$$

where C_t is the total influence coefficient which is in function of concrete biography and can be calculated with the following formula:

$$C_t = C_c \times C_{d.} \times C_a \times C_g \times C_\phi \qquad (11)$$

where:

C_c - cement type;

C_d - cement dosage;

C_a - aggregate nature;

C_g - fine sort (0...1 mm);

C_ϕ - maximum aggregate size.

Fig. 5 Ultrasonic apparatus and test hammer

The partial influence coefficients values are presented in table 9.

Table 9 *Partial influence coefficients for combined methods*

Cement type	C_c	Cement dosage, kg/m^3	C_d	Maximum aggregate size, mm	C_ϕ	Fine sort (0…1) mm, %	C_g
P50 (CEM I 52.5)	1.09	200	0.88	7	1.09	6	0.97
P40 (CEM I 42.5)	1.04	300	1.00	15	1.03	12	1.00
Pa35 (CEM II/A-S32.5R); SR35 (SR I 32.5)	1.00	400	1.13	30	1.00	18	1.03
M30 (CEM II/B-S32.5R)	0.96	500	1.25	70-80	0.96	24	1.06
F25 (CEM III/A 32.5R)	0.90	600	1.31			30	1.09
						36	1.11
						42	1.13
						48	1.15

C_a = 1.00 for river aggregate; for aggregate with another mineralogical nature must be experimental determinate.

Table 10

The reference compressive strength concrete (f_c^{rel}) N/mm^2 (MPa)

v \ n	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52
3000	4.0	4.7	5.3	5.9	6.5														
3100	4.5	5.2	5.8	6.5	7.2	7.8													
3200	5.0	5.7	6.5	7.2	7.8	8.4	9.3												
3300	5.6	6.3	7.1	7.7	8.4	9.2	9.8	10.6											
3400	6.2	6.9	7.6	8.3	9.2	9.8	10.6	11.5	12.5										
3450	6.5	7.3	8.0	8.7	9.5	10.2	11.0	12.0	13.1										
3500	6.8	7.6	8.3	9.1	9.8	10.5	11.4	12.4	13.6	14.6									
3550	7.1	7.9	8.7	9.3	10.2	10.9	11.9	12.9	14.1	15.1									
3600	7.4	8.2	9.0	9.7	10.5	11.3	12.3	13.4	14.6	15.6	16.7								
3650		8.5	9.3	10.0	10.9	11.7	12.8	13.9	15.1	16.2	17.4								
3700		8.7	9.6	10.3	11.2	12.1	13.2	14.4	15.6	16.7	18.1	19.6							
3750		9.1	9.9	10.7	11.6	12.6	13.8	15.0	16.2	17.5	18.9	20.6							
3800		9.4	10.2	11.0	12.0	13.1	14.3	15.5	16.8	18.2	19.7	21.5							
3850		9.8	10.5	11.4	12.5	13.6	14.9	16.1	17.5	18.9	20.6	22.6							
3900		10.1	10.7	11.7	12.9	14.1	15.4	16.7	18.2	19.6	21.4	23.7	25.9	28.0	30.4	32,8	35.0	37,3	39.7
3950		10.3	11.1	12.1	13.4	15.7	15.9	17.2	18.9	20.5	22.4	24.7	26.8	29.0	31.4	33,8	36.0	38,3	40.7
4000		10.6	11.5	12.5	13.8	15.2	16.4	17.8	19.6	21.4	23.4	25.7	27.7	30.1	32.5	34,7	37.0	39,4	41.8
4050			11.9	13.0	14.4	15.7	17.0	18.6	20.5	22.4	24.5	26.7	28.8	31.1	33.4	35,7	38.0	40,4	42.8
4100			12.2	13.5	14.9	16.2	17.6	19.3	21.4	23.3	25.5	27.7	29.8	32.2	34.4	36,7	39.1	41,5	43.8
4150				14.0	15.4	16.7	18.2	20.1	22.4	24.3	26.5	28.8	30.8	33.2	35.4	37,7	40.1	42,5	44.8

Table 10 (continuation)

The reference compressive strength concrete (f_c^{ref}) , N/mm^2 (MPa)

v \ n	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52
4200	14.5	15.9	17.2	18.8	20.9	23.3	25.3	27.4	29.8	31.8	34.1	36.4	38.8	41.2	43.5	45.7
4250		16.4	17.9	19.6	21.8	24.3	26.3	28.4	30.8	32.8	35.1	37.4	39.8	41.2	44.5	46.7
4300		16.9	18.5	20.5	22.7	25.3	27.3	29.4	31.7	33.8	36.0	38.4	40.8	43.1	45.3	47.8
4350				21.5	23.6	26.3	28.3	30.6	32.6	34.7	36.9	39.3	41.7	44.0	46.3	48.8
4400				22.4	24.5	27.3	29.2	31.2	33.4	35.5	37.8	40.3	42.6	45.0	47.4	49.8
4450						28.2	30.0	32.1	34.3	36.4	38.6	41.0	43.5	46.1	48.5	
4500						29.0	30.8	33.0	35.2	37.3	39.9	42.3	44.7	47.2	49.6	
4550							31.8	33.9	36.2	38.4	40.6	43.4	45.8	48.2	50.7	
4600								34.8	37.2	39.6	42.0	44.5	47.0	49.3	52.0	
4650									38.2	40.6	43.1	45.6	48.0	50.5	53.0	
4700									39.3	41.6	44.0	46.8	49.0	51.8	54.2	
4750										42.5	45.0	47.7	50.1	52.8	55.4	
4800										43.5	46.0	48.6	51.3	53.8	56.5	
4850											47.0	49.7	52.2	54.9	57.5	
4900											48.0	50.8	53.2	56.0	58.5	
4950												51.8	54.3	56.9	59.6	
5000												52.8	55.5	57.9	60.7	

4. DESTRUCTIVE DETERMINATION ON HARDENED CONCRETE

Generalities

Mechanical strength is the main criteria to appreciate the quality of hardened concrete (resistance concrete class).

The samples are made from fresh (green) concrete with cubic, cylindrical or prismatic shapes (figure 6)



Fig. 6 Cylindrical, prismatic and cubic concrete samples

For compression strength the cubic samples can have side of 100 mm, 150 mm etc.

For bending tensile strength the prismatic samples can have dimensions of 100x100x550 mm or 150x150x600 mm.

To establish the concrete class the test duration is of 28 days. The samples are kept in water, at normal laboratory conditions, until tested. Before testing the dimensions sample will be checked.

4.1. Compression Strength Determination on Hardened Concrete

Compression strength determination is done by applying an increasing uniform force on cubic or cylindrical samples like in figure 6.

The samples (cubic or cylindrical) are brushed and laid between platens of test machine so that the force activates perpendicular on placed direction of concrete. The force is applied continuously and uniformly until the sample is crushed.

The compressive strength for a sample batch is established like average values of minimum three results.

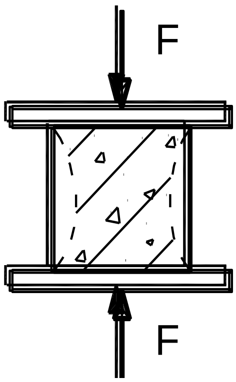


Fig. 7

Compression strength is obtained by:

$$f_C = \frac{F}{A} \qquad [N/mm^2] \qquad (12)$$

where:

F - maximum load until crush sample (N);

A - the surface load area (mm^2).

4.2. Bending Tensile Strength Determination on Hardened Concrete

Bending tensile strength determination is made by applying an increasing uniform force on the middle span between the bearings like in the schedule which is showed in figure 8.

The samples (which are cleaned with wire brush) are laid on the bearings of the test machine so that the force activates perpendicular on the placement direction of concrete. The force is applied continuously and uniformly until the crush sample.

On the samples with 100x100x550 mm or 150x150x600 mm two tests can be made (figure 8).

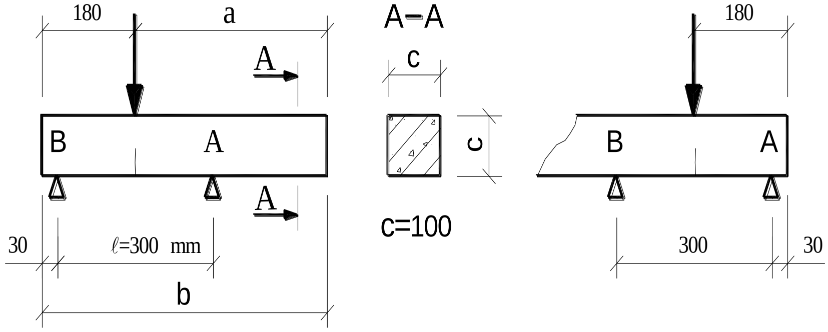


Fig. 8

Bending tensile strength on the hardened concrete is determinate by:

$$f_{ct} = \frac{M}{W_{pl}} = \frac{\frac{P \times l}{4}}{\frac{b \times h^2}{3,5}} = \frac{3,5}{4}\frac{P \times l}{b \times h^2} \qquad (N/mm^2) \qquad (13)$$

where:

M - bending moment (N x mm);

W_p - plastic modulus strength (mm^3);

P - broken force (N);

l - span between bearings (mm);

b - medium width of cross section (mm);

h - medium height of cross section (mm).

The dimensions **b** and **h** are measured perpendicular on longitudinal sample axis nearing to the broken cross section.

The compressive strength for a sample batch is established like average values of minimum three experimental results.

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