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Concrete Technician Handbook

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Dear Valued Customer,

This manual has been prepared by the expert team of Yapıchem for laboratory technicians working in the “Ready Mixed Concrete” industry, taking into consideration the testing stages and application requirements.

In this manual you will find detailed information on tests, sampling techniques, determination methods, instruments, and their applications in written and visual form. Results obtained from tests are presented in detail, and are intended to serve as a reference for the concrete tests that will be performed by your employees as specified here.

Moreover, this manual provides detailed information on the recommended limiting values for concrete mixtures and properties according to the concrete exposure classes, concrete casting in hot and cold weather conditions which affect the ultimate strength and durability of concrete, the causes of possible cracks in fresh and hardened concrete, and the necessary precautions related thereto. Concrete Classes and Strengths Table and Cement Classes Table are provided for informative purposes. This manual is prepared in conformity with the TS EN 206 Standard, and the technical data of TSI and Turkish Ready Mixed Concrete Association. Yapıchem assumes no legal responsibility for any failures resulting from incorrect applications and other such reasons.

Fatih ARICAN
Executive Chairman

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AGGREGATE SAMPLING (TS EN 932-1-932-2)

The most important consideration when sampling an aggregate pile is to ensure that the collected sample is representative of the whole pile. Failing which leads to inaccurate conclusions. The sample should be collected carefully from different areas within the middle section of the pile, not from the top or the bottom. The collected samples should be homogeneously mixed and reduced to an appropriate size for testing. This procedure is performed using the sample splitter or quartering methods. The laboratory sample is placed onto the working surface. The sample is thoroughly mixed and piled-up into a conical heap, from which a sample is taken with a shovel and piled-up to form a new cone. This procedure is repeated 3 times. Each shovelful is deposited on top of the preceding aggregate cone so that the material spills over the cone equally in all directions, ensuring that the various sizes are thoroughly mixed. Mixing and quartering procedure is repeated until the portion specified for the test is obtained.

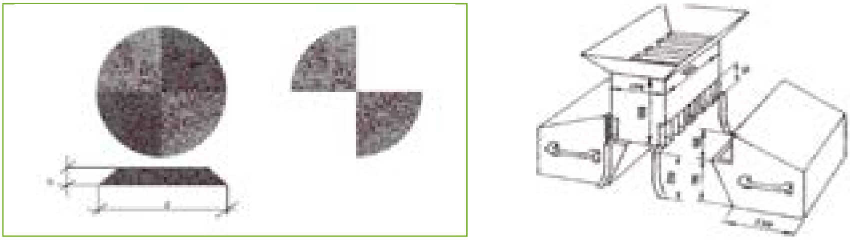


Figure 1: Quartering Method and Sample Splitter

METHODS FOR THE DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION (TS EN 1097-6)

It is necessary to know the specific gravity of the aggregates in order to make the concrete mixture calculation. Specific gravity is the weight per unit volume occupied by aggregate particles.

METHOD FOR THE DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION RATE OF FINE AGGREGATES

Instruments

- Scales: A scale with 0,1 g accuracy and a 2 kg capacity
- Hot Plate or Air Blast Heater A gas or electrically heated hot plate or air blast heater powerful enough to raise the temperature in the immediate vicinity of the test sample to 105°C ± 5°C.
- Measuring Cup: A measuring cup of 500 ml or 1000 ml
- Glass Plate: A glass plate large enough to cover the measuring cup
- Metal Mould: A truncated conical-shaped metal mould with an upper inner diameter of 40 ± 3 mm, lower inner diameter of 90 ± 3 mm, height of 75 ± 3 mm and wall thickness of at least 0.8 mm.
- Metal Compactor: A metal compactor weighing 340 ± 15 g and having a flat circular compacting surface with a diameter of 25 ± 3 mm.
- Vacuum Pump
- A tower or similar materials for drying, pans, trowel, fan, desiccator, and thermometer

Test Sample

The sample quantity used in tests varies depending on the maximum grain size. The suitable amount (kg) for each test sample is provided in *Graph 1.*

Maximum grain size (mm)	0,25	0,50	1	2	4	8	16	31,5
Test sample quantity (kg)	0,8	0,8	0,8	0,8	0,8	1,5	2	2

Graph 1: Test Sample Quantities Required for the Determination of Specific Gravity

Procedure

The test sample prepared in accordance with TS EN 932-2 and in the approximate quantity specified in *Graph 1* is submerged in water for 24 hours. Afterwards, the water is drained carefully to prevent the loss of tiny grains, and the sample is spread out evenly onto a pan. The pan is placed on the hot plate to dry the sample. If necessary, the sample can be dried faster and brought to a saturated dry surface state with a moving stream of air by means of a fan while stirring continuously. Saturated dry surface state is reached immediately after the fine aggregates transition from a dark (wet) color to a light (dry) color. The visual determination of the saturated dry surface state relies on the experience of the tester. The sample must not be dried too much. The truncated cone or cutting method shall be used if it cannot be determined whether the sample is brought to saturated dry surface state visually.

Determination of the Saturated Dry Surface State Using the Truncated Cone Method

The sample assumed to have reached saturated dry surface state is placed into the truncated conical shaped metal mould with its wider surface facing downwards, its surface is lightly tamped 25 times with a tamping rod, then the mould is lifted vertically and removed. Samples retaining their solid shape upon removal of the mould indicates the presence of free moisture.

In which case, it becomes necessary to continue the drying process and to carry out truncated cone method once again. Conical shaped samples freely collapse when saturated dry surface state is achieved. If, for any reason, the sample is dried too long, it is necessary to apply a spray of water and stir to rehydrate the sample, and to carry out the truncated cone method.

Determination of the Saturated Dry Surface State Using the Cutting Method

The sample assumed to have reached saturated dry surface state is shaped into a roughly hemispherical pile.

The pile is split vertically with using a trowel. If the resulting surface remains flat, the pile must be further dried. Saturated dry surface state is reached when the vertical surface can no longer support itself and collapses.

The sample, upon reaching saturated dry surface state, is weighted and the saturated dry surface weight (W^1) is recorded.

The sample is brought to the oven-dry state. Then, the sample is placed in a desiccator and cooled to room temperature. Once cooled, the sample is poured into a measuring cup and weighted.

The previously determined weight of the measuring cup is subtracted from this measurement to calculate the dry weight of the sample (W^2). The measuring cup is filled halfway with water at approximately 20°C and then lightly tapped *(Figure 2)* as well as stirred to remove any air bubbles. Vacuum pump may be used to accelerate the removal of air bubbles. After one hour, the measuring cup is filled with water at approximately 20°C to 500 ml

(or 1000 ml) mark and weighted (W^3).

$$\text{Specific Gravity} = \frac{W^1}{(W^1 + W^2) - W^3}$$

W^1: Sample weight
W^2: Weight of the measuring cup filled with water
W^3: Sample+water+container

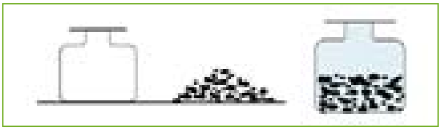


Figure 2: Specific Gravity Measuring Cup (Pycnometer))

$$\text{Su Emme} = \frac{W^1 - W}{W}$$

W: Dry material W_1: Ssd sample

SIEVE ANALYSIS TEST (TS EN 933-1)

The purpose of the sieve analysis test is to determine the weight ratio of grain size distribution of aggregates to the whole aggregate mixture *(Figure 3)* and the percentage of aggregates in 1 m³ of concrete by means of sieving the aggregates through square-mesh test sieves.

Figure 3 : Aggregate Piles of Different Grain Diameters

Maximum Grain Diameter

Maximum grain diameter is the smallest aperture size through which an aggregate mixture can pass during a sieving process.

Coarse Aggregate

Coarse aggregate refers to aggregates retained on sieves with 4 mm aperture size.

Fine Aggregate

Fine aggregate refers to aggregates passing through sieves with 4 mm aperture size.

Mineral Filler Material

Mineral filler materials refer to materials passing through sieves with 0.063 mm aperture size.

Tools

Scales: Scales, capable of weighing the test samples with a sensitivity of at least 0.1%
Sieves: Wire sieves compliant with TS ISO 3310-1
Drying Oven: A drying oven of sufficient size capable of maintaining a temperature of 110 ± 5°C
Sample Splitter: The sample splitter shown in *Figüre 1*

Preparation of Test Sample

The aggregate sample is homogeneously mixed, and the portion required for the test is separated using the sample splitter. You can also use the quartering method to divide and prepare the test sample.

Using this method, the aggregate is shaped into a smooth circular pile and divided into four equal parts using the sharp edge of a trowel. (TS EN 932-2)

Conducting the Test

The test sample is heated to a constant mass at 110 ± 5°C. Then, the sample is allowed to cool, weighed and the measured mass is recorded as M1.

The test sample is placed in a container, and the container is filled with sufficient amount of water. It is recommended to keep the sample immersed in water for 24 hours to separate any lumps. A dissolving agent may also be used.

Both sides of the sieve with 0.063 aperture size (designated for this test only) is dampened, and a protective sieve (for example, with 1 mm or 2 mm aperture size) is placed on top of it. The sieves should be positioned so that the passing suspension is collected as waste or, where appropriate, in a suitable container. The materials collected in the container is poured over the topmost sieve. The washing procedure is repeated until water passing through the test sieve with 0.063 mm aperture size becomes clear. Precautions must be taken to avoid overloading, overflowing, or damaging the protective sieve or the test sieve with 0.063 mm aperture size. For some aggregates, only the fine grains collected in the container need to be poured over the test sieve with 0.063 mm aperture size with protective sieve. Coarse grains remaining in the sample cup is washed and fine grains are sieved through the protective sieve until the water passing through the test sieve with 0.063 mm aperture size becomes clear.

The material retained on the sieve with 0.063 mm aperture size is heated to a constant mass at 110°C ± 5°C. Then, the sample is allowed to cool, weighed and the measured mass is recorded as M2. The washed and dried material (or the dry sample) is poured over the sieve column.

Sieving

The column is shaken manually or mechanically. Then, the sieves are separated one by one, starting with the sieve with largest aperture size. Each sieve is manually shaken using a pan and cover, ensuring that no material is lost.

The efficiency of mechanical sieving is affected by parameters such as the aggregate type, sieving duration, sieve load, and the amplitude and frequency of the vibration. Therefore, the duration of mechanical sieving must be determined carefully. Materials passing each sieve is place on the next sieve in the column.
Depending on the properties of the aggregate, sieving procedure is deemed complete if the amount of material retained on the sieve does not change more than 1.0% within 1 minute interval.
The material retained on the sieve with the largest aperture size is weighed, and its mass is recorded as R1. The same procedure is repeated for the sieve nested below the sieve with the largest aperture size, and its mass is recorded as R2.

The same procedure is repeated for all sieves in the column to obtain the mass of the materials retained on each sieve. Their masses are recorded as R3, R4, RI and Rn.

The mass of materials retained on each sieve M1 is calculated as a percentage of their original dry mass. The cumulative percentage of the original dry mass passing each sieve, excluding the sieve with 0.063 aperture size, is calculated. The fine grain percentage passing (f) from the sieve with 0.063 aperture size is calculated with the below equation.

$$f = \frac{(M1-M2)+P}{M1} x100$$

Where;

M1: Dry mass of the test sample (kg),

M2: Dry mass of the material retained on the sieve with 0.063 aperture size (kg),

P: Mass of sieved material retained on the pan (kg)

For Dry Sieving: $f = \frac{100P}{M1}$

Figure 4: Sieve Analysis Set

PREPARATION OF METHYLENE BLUE SOLUTION

Instruments

- 1000 g pure water
- Methylene blue powder
- Scales: A scale with 0,1 g accuracy and a 2 kg capacity
- Shaker operating at 600 and 400 rpm.
- 1000 ml glass beaker
- Chronometer

Procedure

750 grams of pure water is poured into the glass beaker. 19 grams of methylene blue powder is added into the water. The mixture is shaken at 600 rpm for 45 minutes and poured into a separate container. The mixing propeller and the glass beaker are thoroughly cleaned with the remaining 250 grams of pure water, which is then added to the prepared solution. Wait for 24 hours before using the solution and ensure the solution is kept in an airtight container. The shelf life of this solution is 28 days. In order to conduct reliable experiments, the solution should be replaced after 28 days .

METHYLENE BLUE TEST (TS EN 933-9)

Instruments

- Scales: A scale with 0,1 g accurarcy and a 2 kg capacity
- Titrometer
- Shaker operating at 600 and 400 rpm.
- Glass rod
- 1000 ml glass beaker
- Pure water
- Filter paper
- Methylene blue solution
- Sieve no 2
- Pan
- Chronometer

Procedure

Methylene blue test is carried out using the set shown in Figure 5. The fine aggregate is sieved through the sieve no 2, and 200 grams of the passing material is added into 500 grams of pure water and the resulting mixture is shaken at 600 rpm for 5 minutes. Titrometer is filled with 100 ml of blue liquid. 5 ml of methylene blue solution is added into the liquid after 5 minutes, and the mixture is shaken at 400 rpm for 1 minute. After the liquid is thoroughly mixed, the glass rod is dipped into the mixture and the liquid is dripped onto the filter paper to observe the formation of a halo. Repeat this process until a halo can be observed by adding 5 ml of solution and shaking the mixture at 400 rpm for 1 minute.

If the resulting halo disappears within the first 4 minutes, another 5 ml of dye solution is added into the mixture. If the resulting halo disappears in 5 minutes, only 2 ml of dye solution is added into the mixture. Continue stirring and performing tests until the halo remains visible for 5 minutes.

Formula: MB=V1/M1*10

Where;

M1 : Dry mass of the test sample.

V1 : Total volume (ml) of the added dye solution.

MB value, indicating the amount of dye used per kilogram for the 0 - 2 mm beaker range, is recorded with a precision of 0.1 grams.

Note: The number 10 in the above equation is used to convert the volume of the dye solution used into the mass of dye adsorbed per beaker kilogram of the range tested.

Figure 5: Methylene Blue Set

DETERMINATION OF MOISTURE CONTENT OF AGGREGATE (TS 3523)

A sample is taken from the aggregate using appropriate methods. The sample is then weighed, and its weight recorded. The weighed aggregate is heated either in a drying oven or on a stove, until it becomes oven dry. Oven-dry is defined as the state in which the pores of aggregate grains are completely dry. The oven-dry aggregate is weighed after cooled. The following equation is then used to calculate the moisture content in the aggregate pile.

$$\text{\% Aggregate Moisture Content} = \frac{\text{First Weight - Oven-dry Weight}}{\text{Oven-dry Weight}} \times 100$$

GRANULOMETRY TEST

Granulometry

Sieve No (mm)	% MATERIAL PASSING THE SIEVE			REQUIRED LIMITING (TS 706) VALUES
	I.CRUSHED STONE	II. CRUSHED STONE	SAND	
32	100	100	100	100
16	10	85	100	89-62
8	4	35	100	77-38
4	0	5	100	66-23
2	0	0	80	53-14
1	0	0	52	42-8
0.5	0	0	28	28-6
0.25	0	0	8	15-2

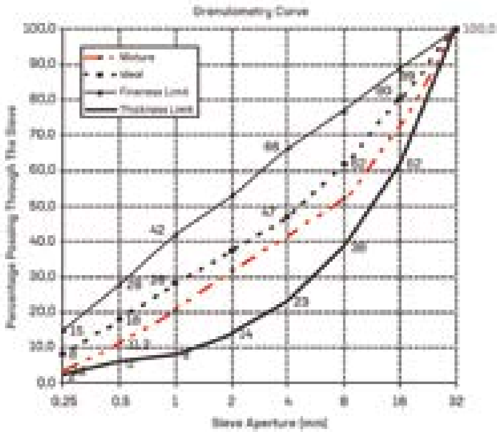
Graph 2: Limiting Values of the Percentage Material Passing the Sieve

The curve that illustrates the distribution of various sizes of grains in an aggregate is referred to as Granulometry Curve. The granulometry curve of an aggregate is determined using the sieve analysis test. Sieves from 3 different basic square-mesh sieve sets are used in the sieve analysis test pursuant to TS EN 12620. The procedure for conducting a sieve analysis test on an aggregate pile is outlined in TS EN 933-1. An example for the % material passing the sieves is provided in *Graph 2*

Maximum Grain Diameter

According to the data, the maximum grain size of the aggregate is 32 mm. The mixture ratio of the aggregates is determined at this stage, considering that crushed stone I, crushed stone II and sand will be used together.

According to the assessments made with the information provided in the aggregate section, a mixture with a granulometry curve as shown in *Graph 3* is obtained by mixing 25% crushed stone I, 35% crushed stones II and 40% sand.



Graph 3: Granulometry Curve

DETERMINATION OF SLUMP TEST (TS EN 12350-2)

Fresh concrete is filled and compacted in a truncated conical-shaped metal mould. The resulting slump of the fresh concrete after the mould is lifted and removed is used to assess the consistency of the concrete. A step-by-step depiction of the slump test is provided in *Figure 6*

Figure 6: Slump Test

Instruments

The mould is a 1.5 mm or thicker metal instrument that is resistant to the adverse effects of cement paste for a brief period of time and is utilized to form test samples. The inner surface of the mould should be smooth and free of any grooves and notches, and protrusions such as rivet heads. The mould should be hollow and have a truncated conical shape with the following internal dimensions.

- Base diameter: (200 ± 2) mm
- Surface diameter: (100 ± 2) mm
- Height: (300 ± 2) mm

The upper and lower surfaces of the mould should be open, parallel to each other, and perpendicular to the longitudinal axis of the mould. There should be two handles near the upper surface and fixing clamps or foot clamps near the lower surface of the mould to ensure stability during testing. Moulds with fixing clamps attached to the lower surface can only be used if loosening and removal of the clamps does not affect the stability of the mould and the slumping of the concrete.

Tamping Rod, shall be made of mild steel with a circular cross-section, 600 ± 5 mm in length, 16 ± 1 mm in diameter, and having a rounded end.

Conical Funnel (Optional), is a non-absorbent metal instrument that is resistant to the adverse effects of cement paste for a brief period of time, and has a snap ring for attaching to the mould..

Ruler, marked from 0 mm to 300 mm, with a maximum interval of 5 mm. The zero line should be located at the end of the ruler.

Base Plate/Surface, should be a non-absorbent and non-flexible flat plate or similar surface used to hold the mould.

Remixing Container, is a non-absorbent and rigid flat tray that is resistant to the adverse effects of cement paste for a brief period of time. The dimensions of the tray should be suitable for remixing all concrete with a square shovel.

Class	Slump (mm)
S1	10-40
S2	50-90
S3	100-150
S4	160-210
S5	> 220

Graph 4: Millimeter Ranges Pursuant to Slump Classes and Standards

Test

The inner surface of the mould and the base plate is dampened, ensuring that the surface remains free of any free water, and the mould is placed on the horizontally positioned base plate/surface. The mould, either by clamping to the base or pressing onto the two feet clamps, is firmly fixed to the base plate/surface while pouring the concrete.

Fresh concrete is poured into the mould in three layers of equal thickness, each layer constituting approximately 1/3 of the mould height when compacted. Each layer is compacted using a tamping rod 25 times during pouring. The strokes of the tamping rod should be distributed evenly over the surface of each layer. The tamping rod should be slightly tilted vertically, and at least half of the strokes should be made at points that would form a spiral from the edge to the center in order to distribute the strokes evenly over the surface while tamping the lowest layer.

The second and final layer must be compacted to its full depth, so that the tamping rod slightly penetrates the lower layer. While filling and compacting the first layer, it is important to ensure that the height of the concrete exceeds the surface of the mould before compacting. If the height of fresh concrete falls below the surface level of the mould while compacting the first layer, additional concrete should be added to ensure that the height of the concrete remains above the surface of the mould. After the compaction procedure is completed, any excess concrete should be removed from the upper surface of the mould using cutting and bending motions (similar to using a gauge) and the surface should be leveled. Concrete spilled on the base plate/surface should be cleaned.

Using the handles, the mould is lifted vertically upwards and removed. The mould should be removed within 2-5 seconds and at a constant speed, without any lateral movement or twisting motion to affect the concrete mass.

The entire test, from the pouring of concrete to the removal of the mould, should be completed within 150 seconds without any interruption.

DETERMINATION OF DENSITY AND AIR CONTENT OF FRESH CONCRETE BY PRESSURE MEASUREMENT METHOD

The unit weight of fresh concrete is defined as the weight per unit volume of fresh concrete filled and compacted into a given volume and is expressed in kg/m^3.

Air content in concrete is defined as the percentage ratio of the volume of air to the volume of concrete, excluding the closed voids in aggregate.

Density of Fresh Concrete (TS EN 12350-6)

Fresh concrete is placed and compacted in a sealed container of known volume and mass, and then weighed.

The volume of the container must be at least 5 lt. The container should be filled in two or more layers to ensure complete compaction depending on the consistency of the concrete and the compaction method used.

The container should be filled in a single layer if self-compacting concrete is used. The concrete, immediately after being placed in the container, shall be compacted fully without segregation and excess grouting.

No compaction procedure is carried out for self-compacting concrete. The minimum sufficient time should be used when compacting with internal vibrator. Excessive vibration that would cause the discharge of entrained air should be avoided.

When using a vibrating table, the container should preferably be clamped onto the table and the procedure should be performed for the minimum sufficient time. When compacting by hand using a circular section or prismatic rod, the strokes of the tamping rod should be distributed evenly over the cross-sectional area of the container. For concretes having a consistency equivalent to slump class S1 and S2, each layer should typically be compacted using a tamping rod 25 times until any air pockets or entrapped air is removed while avoiding the discharge of entrained air.

The outer edges of the container should be tapped with the tamping rod until large air bubbles cease to appear on the surface and the voids left by the strokes of the tamping rod is filled.

The top surface of the container should be leveled with a steel trowel or a smoothing trowel once the top layer is compacted. The surface should be scraped with a straight edge gauge and the concrete height should be aligned with the upper edges of the container. Then, the outer surface of the container should be cleaned.

The filled container is weighed on the scale and the net weight of the concrete is determined by subtracting the tare weight of the container from the gross weight.

The density of the fresh concrete (D) is calculated using the below formula. The result is expressed in kg/m^3 and is rounded to the nearest 10 kg/m^3.

$$D=\frac{M2-M1}{V}$$

Where;

D: Density of fresh concrete kg/m^3
M1: Weight of the empty container kg
M2: Total weight of the container with concrete sample kg
V: Volume of the container m^3

Air Content of Fresh Concrete (TS EN 12350-7)

The flanges of the container and cover assembly should be thoroughly cleaned. The cover assembly should be placed and fixed to the container. It is important to make sure that there is no pressure leak between the cover and the container.

The main air valve is closed, and the valves A and B are opened. The device is filled with water using an injector through the valve A or B until water emerges from the other valve, and the device is lightly tapped with a tamping rod until the water bubbles are completely removed. The air release valve

connected to the closed air cell is closed, and air is pumped into the closed air cell until the pressure gauge needle reaches the initial pressure zero line.

After waiting for a couple of seconds to allow the compressed air to cool to ambient temperature, the pressure gauge needle is brought to the initial pressure line by either pumping air or draining pressurized air. Pressure gauge is lightly tapped during this procedure.

A and B valves are closed, main air valve is opened. The sides of the air meter are tapped firmly. The value indicated by the pressure gauge needle after the pressure gauge is lightly tapped by hand a couple of times and the needle is stabilized is read as A1.

After the test is complete, the pressurized air is drained by opening the valves A and B, and the cover assembly is removed by loosening the fixing clamps.

Figure 7: Air Measurement Device

PREPARATION OF CONCRETE TEST SAMPLES (TS EN 12350-1)

Place of Sample Preparation

Concrete test samples should be prepared at, or as near as possible to, their place of storage. Samples should be moved to their place of storage immediately after preparation. Samples should not be shaken or otherwise disturbed while moving.

Placement of Concrete into Sample Moulds

Concrete is placed into sample moulds in two layers. The shovel, scoop or trowel used to pour concrete into the mould should be moved alongside the surface of the mould to ensure that the concrete is distributed homogeneously within the mould and the segregation of coarse aggregates is prevented. A tamping rod is used when necessary to ensure that the concrete spreads across the mould. The concrete filled as the last layer should be sufficient to fill the mould completely after compacting. In cases where the mould is not filled completely it is important to make sure that the concrete added is representative of the concrete mixture.

Compaction of Concrete in Sample Moulds

Compaction Methods

Compacting methods such as rodding, and internal and external vibration can be used while preparing concrete test samples.

Also, if not otherwise specified, the compaction method used is determined according to the workability (slumping) of the concrete. Concretes with a slump value less than 2.5 cm should be compacted by vibration,

whereas concretes with a slump value greater than 7.5 cm should be compacted by rodding. Concretes with a slump value between 2.5 cm and 7.5 cm can be compacted using both methods.

NOTE: The methods provided in this standard may not be sufficient for compacting concretes with very low water content and slump value. Compaction methods recommended in the relevant standards or specifications can be used while compacting such concrete.

Rodding: The concrete is placed into the mould in layers of approximately equal volume (depth) and rodded 25 times with the rounded end of the tamping rod.

Required number of strokes for each layer in cylindrical moulds is specified in *Graph 5*

Cylinder Diameter < cm	Number of Strokes for Each Layer
15	25
20	50
25	75

Graph 5: Number of Rodding Strokes

The required number of rodding strokes for each layer in cubical or beam moulds is calculated as one stroke per 15 cm² of the upper surface area the mould. The strokes should be distributed evenly over the mould surface. The strokes should penetrate the entire depth while rodding the lowest layer, making sure the bottom of the mould is not struck too firmly. While rodding the other layers, the strokes should be arranged so that the rod penetrates approximately 2,5 cm into the layer below. Any voids that may occur while rodding should be removed by lightly tapping on the edges of the mould. Corners and edges of the rodded layer should be leveled using a trowel.

Vibration: The concrete is placed into the mould in layers of approximately equal volume (depth). The internal vibration procedure for each layer should be carried out after the entire layer is placed in the mould. The duration of vibration procedure shall be determined according to the consistency of the concrete for each layer, type of the vibrator and sample mould.

Sufficient vibration is usually indicated by a smooth and shiny surface of the concrete layer. Excessive vibration that might cause segregation in concrete should be avoided.

The amount of concrete filled as the last layer should be arranged to ensure that any overflowing concrete after vibration is less than approximately 6 mm in height. If the mould is not completely filled after vibration, the added concrete should overfill the upper surface of the mould by 3 mm.

Leveling of Sample Surfaces

The surface of concrete placed in the mould is polished after compaction. For that purpose, the concrete overflowing from the upper surface of the mould is removed with a tamping rod or a trowel, and the leveled surface is polished with a trowel or a gauge. These procedures should be completed as quickly and practically as possible. The sample surface obtained should be even with the edges of the mould, and the dimensions of any remaining indentations or protrusions should not exceed 3 mm.

Figure 8: Concrete Sample Moulds

DETERMINATION OF COMPRESSIVE STRENGTH OF TEST SAMPLES (TS EN 12390-3)

The samples are loaded to failure in a compression testing machine *(Figure 9)* conforming to EN 12390-4. The maximum load sustained by the specimen is recorded and the compressive strength of the concrete is calculated. Compression testing machine should be conforming to EN 12390-4.

Preparation and Placement of the Sample: Any moisture remaining on the surface of the sample is dried before it is placed in the testing machine.

The surface of the loading heads of testing machine should be wiped clean, and any loose protrusion or material is removed from the surface of the sample that will be in contact with the heads.

Nothing other than spacing blocks (EN 12390-4) and auxiliary platens should be placed between the test sample and the loading head of the testing machine.

Cubic samples should be placed so that the load is applied perpendicularly to the direction of pouring.

Samples should be positioned to sit at the center of the lower loading head of the machine. The specified dimensions of cubic samples and the specified dimensions of the cylindrical samples should be positioned to sit at the center with ± 1% accuracy. The auxiliary loading platens, if any, should be adjusted according to the lower and upper surfaces of the sample.

With two-column testing machines, cubic samples should be placed with their troweled surface

Loading: A constant rate of loading should be determined between 0.2 MPa/s (N/mm².s) and 1.0 MPa/s (N/mm².s). The load shall be applied to the sample without impact and increased continuously at the determined constant rate with less than ± 10 % deviation until no greater load can be sustained.

Displaying Results: Compressive strength is calculated using the equation below:

f_c:F/A_c

Where;

fc: Compressive strength MPa (N/mm²)

F: Load value at failure point, N

Ac: Cross-sectional area (mm²) of the sample upon which the load is applied

This is calculated using the specified dimensions of the sample (EN 12390-1) and using the actual measured dimensions of the sample.

Compressive strength is rounded to the nearest 0.5 MPa (N/mm²).

Figure 9: Concrete Compression Machine

Concrete exposure classes table, concrete casting in hot and cold weather conditions which affect the ultimate strength and durability of concrete, and the causes of possible cracks in fresh and hardened concrete, and the necessary precautions related thereto to be considered in the selection of the suitable concrete class and the determination of the mixture is provided below. Concrete classes and strengths table and cement classes table are provided for informative purposes.

- Recommended Limiting Values for Concrete Mixtures and Properties
- Concrete Casting in Hot Weather Conditions
- Concrete Casting in Cold Weather Conditions
- Types of Cracks in Reinforced Concrete Structures
- Cement Classes Table
- Cement Classes and Strengths Table

RECOMMENDED LIMITING VALUES FOR CONCRETE MIXTURES AND PROPERTIES (TS 13515)

Graph F.1.1

		No Corrosion Effect and Risk	Corrosion due to Carbonization			
Rank	**Exposure Class**	**Xo [2]**	**XC_1**	**XC_2**	**XC_3**	**XC_4**
1	Largest Water/Cement Ratio	–	0,70	0,65	0,60	0,55
2	Lowest Concrete Class [b]	C8/10	C20/25	C25/30	C230/37	C30/37
3	Minimum Cement Content [c] (kg/m^3)	–	250	260	270	280
4	Minimum Cement Content when Mineral Additive is Used [c] (kg/m^3)	–	240	240	240	270
5	Minimum Air Content (%)	–	–	–	–	–
6	Other Properties					

(a) For concrete without reinforcement or embedded metal only.

(b) Not applied to light concrete.

(c) Cement content can be reduced 30 kg/m^3 for concretes with maximum aggregate grain size 63 mm.

	Reinforcement Corrosion					
	Corrosion due to Chloride Ions					
	Chloride apart from Seawater			Chloride from Seawater		
	XD_1	XD_2	XD_3	XS_1	XS_2	XS_3
	0,55	0,50	045			
	C30/37[d]	C35/45[de]	C35/45[d]			
	300	320	320	see XD_1	see XD_2	see XD_3
	270					
	–	–	–			
–						

(d) A concrete with lower limiting value for air entrained concretes (such as compliance with the environmental exposure class XF). In such case, footnote (e) is not applied.

(e) One lower class is applied for concretes with a slower strength gain rate.
(when fcm, 2/fcm, 28 < 0,30). In such case, the compression strength for classification is determined with 28-days samples as in Article 4.3.1.

RECOMMENDED LIMITING VALUES FOR CONCRETE MIXTURES AND PROPERTIES (TS 13515)

Graph F.1.2

		Freeze-Thaw Exposure					
Rank	**Exposure Class**	**XF_1**	**XF_2**		**XF_3**		**XF_4**
1	Largest Water/Cement Ratio	0,60	0,55 [g]	0,55 [g]	0,55	0,55	0,55 [g]
2	Lowest Concrete Class [b]	$C_{25/30}$		$C_{35/45}$ [e]	$C_{25/30}$	$C_{35/45}$ [e]	$C_{30/37}$
3	Minimum Cement Content [c] (kg/m³)	280	300	320	300	320	
4	Minimum Cement Content when Mineral Additive is Used [c] (kg/m³)	270	270 [g]		270		270 [g]
5	Minimum Air Content (%)	–	f	–	f	–	f and j
6	Other Properties	Grain size distribution for concretes of expose class XF_1 to XF_4					
		F_4	MS_{25}		F_2		MS_{18}

See *Graph F.1.1* for the footnotes (b), (c), (d) and (e).

(f) The average air content of concrete immediately before placement shall be; at least 5.5% per volume for concretes with a maximum aggregate grain size of 8 mm, at least 4.5% per volume for concretes with a maximum aggregate grain size of 16 mm; at least 4% per volume for concretes with a maximum aggregate grain size of 32 mm, and at least 3.5% per volume for concretes with a maximum aggregate grain size of 63 mm. The maximum allowable deviation of a single test result from the above test results is -0.5 %.

(g) Only fly ash shall be taken into consideration as a binding mineral additive added into the cement in the calculation of the minimum cement content and water/cement ratio No other type II mineral additives shall be taken into consideration in this calculation. Fly ash shall not be taken into consideration in the calculation if fly ash and silica are used together in the concrete

	Reinforcement Corrosion					
	Hazardous chemical environment			Abrasion [h]		
	XA 1	**XA 2**	**XA 3**	**XM 1**	**XM 2**	**XM 3**
	0,60	0,50	0,45	0,55		0,45
	$C_{25/30}$	$C_{35/45}$ [d,e]	$C_{35/45}$	$C_{30/37}$ [d]		$C_{35/45}$ [d]
	280	320		300 [l]		320 [l]
	270					
	–					
	–		–	Concrete surface operated[k]		Using coarse aggregate

(h) Aggregate used shall comply with EN 12620.

(i) Maximum cement content should be 360 kg/m³ apart from high-strength concrete.

(j) Air entrainment is not required for concretes having the consistency of damp earth with a water/cement ratio of less than 0.40.

(k) Such as vacuuming the water and leveling the surface.

(l) See Article 5.3.2 for protective measures.

CONCRETE CASTING IN HOT WEATHER CONDITIONS

TS 1248 defines the weather condition when the average temperature exceeds 30°C for three consecutive days as "extremely hot weather".
TS 1247 defines concrete casting temperature at normal weather as +5°C to +30°C.
According to TS 13515, the temperature of fresh concrete should not exceed 35°C if no precautions are taken. Concrete mixing and placement temperature should be 10°C - 30°C. If the cement content of the concrete is less than 240 kg/m3 or in cases where cement with low hydration temperature is used, concrete placement temperature should not fall below 10°C. The temperature of the concrete placed into the mould should not exceed 65°C as it continues to hydrate and harden. The temperature of the concrete placed into the mould should not be less than 5°C when the temperature is between.

The Effects of Hot Weather on Concrete:

- The water content of the mixture increases
- The rate of slump loss increases.
- Concrete temperature (hydration) increases. Concrete sets in less time.
- Plastic shrinkage cracks increase.
- Air content becomes difficult to control in air entrained concretes.

The Effects of Hot Weather on Hardened Concrete:

- Gains strength rapidly during the first days, but 28-day strength becomes lower.
- A porous concrete with high water permeability is obtained due to more water content.
- The tendency of concrete to crack increases due to the temperature difference after the concrete has cooled.
- More shrinkage occurs.

Necessary Precautions:

- Using cement with low hydration temperature.
- Cooling materials forming the concrete.
- Using additives.
- Taking precautions to prevent water from evaporating.
- Avoiding exposing concrete to direct sunlight.
- Cooling the mould and reinforcement before casting.
- Wrapping columns with wet sacks.
- Performing the curing procedure as quickly as possible.
- Reducing the wind exposure.
- Using chemical additives that retards setting.

ONCRETE CASTING IN COLD WEATHER CONDITIONS

Definition of Cold Weather

TS 1248 standard defines cold weather as the weather condition when the average temperature falls below 5°C and does not exceed 10°C for more than half a day for three consecutive days.

Concrete Casting in Cold Weather Conditions

TS 1248 defines the weather condition when the average temperature falls below +5°C for three consecutive days as "cold weather".

Freezing during the setting of fresh concrete is dangerous. The effects of freezing before setting and after hardening are relatively minor. A decrease in temperature of the environment the fresh concrete is cast will prolong the setting and moulding times, reduce the strength of concrete, and may cause aggregate segregation. Maintaining concrete temperature above a certain level at the beginning is essential for protecting the concrete in cold weather. The concrete should be protected from frost for 48 hours if the temperature of the environment the fresh concrete is cast falls below +5°C within a day, and for 72 hours if the temperature stays below +5°C for more than a day. Turkish standards acknowledge that concrete will not be damaged by frost after reaching a compressive strength of 50 kgf/cm². This means 3 days at +10°C for high-quality concrete.

Required Temperatures for Concrete Prepared and Placed in Cold Weather

Thickness of concrete cross-section (cm)	Minimum temperature (°C) Required in Placement
<30 cm	13°C
30-90 cm	10°C
90-180 cm	7°C
>180 cm	5°C

Minimum Temperatures for Concrete after Failure

Thickness of concrete cross-section (cm)	The required concrete mixture temperatures during preparation at the specified air temperatures, (°C)		
	Less than -18°C	Between -18°C and -1°C	Between -1°C and 16°C
<30 cm	21°C	18°C	16°C
30-90 cm	18°C	16°C	13°C
90-180 cm	16°C	13°C	10°C
>180 cm	13°C	10°C	7°C

Necessary Precautions for Cold Weather Conditions:

- Heating the materials forming the concrete to increase the temperature of the concrete mixture,
- Using cement, additives, and concrete antifreeze to ensure high strength during the first days,
- Using suitable moulds and insulation materials and/or curing methods for concrete cast in cold weather,
- Planning ahead and making preparations before casting,
- Concrete cast in cold weather should be cured for a sufficient amount of time.

TYPES OF CRACKS IN REINFORCED CONCRETE STRUCTURES

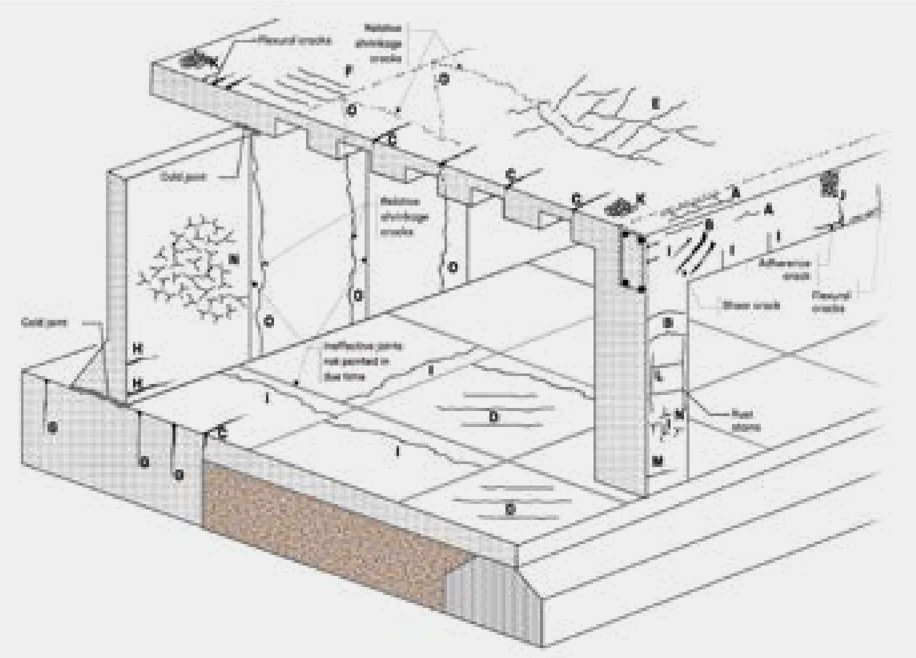


Figure 10: Types of Cracks in Reinforced Concrete Structures

Types of Cracks in Reinforced Concrete Structures

Plastic Settlement (A-B-C)

Formation Time:	Formation Frequency:
10 minutes - 3 hours	Very Frequently

Most Seen On

Deep Sections, Tops of Columns, Ribbed and Waffle Slabs

Main Causes:
- Excessive bleeding and precipitation of heavier particles in the mixture

Secondary Causes:
- Fast drying, areas exposed to sun and wind
- Slow setting due to retarder additives and cement properties

Possible Precautions:
- Vibrating if the concrete is still plastic
- Protection from dry weather conditions
- Reducing bleeding
- Using air entraining concrete

Comment:
Cracks vary in depth and typically occur in the direction of applied stress.

Plastic Shrinkage (D-E-F)

Formation Time:	Formation Frequency:
30 minutes - 6 hours	Very Frequently

Most Seen On

Roads and Slabs (D), Reinforced Concrete (E-F)

Main Causes:
- Water evaporation from the concrete surface due to rapid drying conditions such as exposure to sun and wind causing more shrinkage than bleeding of the concrete, reinforcement near the surface

Secondary Causes:
- Low bleeding rate

Possible Precautions:
- Ensuring high humidity by improving early curing process in addition to precautions that can be taken for plastic setting.
- Adding polypropylene fibers to concrete
- Early curing

Comment:
Cracks rarely extend to the end of the section or are longer than 1 m. They do not extend into aggregate grains.

Early Thermal Shrinkage (G-H)

Formation Time:	Formation Frequency:
1 day - 3 weeks	Very Frequently

Most Seen On

Thick Walls, Thick Slabs

Main Causes:
- Excessive heat due to cement hydration
- Extreme temperature changes

Secondary Causes:
- Rapid cooling
- Insufficient reinforcement distribution
- Excess joint gap

Possible Precautions:
- Reducing heat with low temperature cement or insulating
- Increasing reinforcement distribution
- Adding steel fiber reinforcement

Comment:
The planner should keep in mind the thermal properties of the concrete while checking for cracks and to determine the joint spacing on flooring, slabs, and walls.

Types of Cracks in Reinforced Concrete Structures

Long-Term Drying Shrinkage (I)

Formation Time: A couple of weeks or months

Formation Frequency: Rare

Most Seen On

Thin Slabs and Walls

Main Causes:
- Insufficient joints
- Incorrect design

Secondary Causes:
- Excessive Shrinkage (Shrinkable aggregate)
- Insufficient curing
- Insufficient reinforcement distribution

Possible Precautions:
- Reducing water content
- Curing
- Increasing reinforcement distribution
- Using low shrinkage aggregates

Comment:
Typically caused by an essential design or construction error.

Thin Surface Cracks (J-K)

Formation Time: 1 - 7 days

Formation Frequency: Often, a lot

Most Seen On

Gross Concrete, Slabs

Main Causes:
- Impermeable mould
- Excess polishing

Secondary Causes:
- Cement rich surface
- Insufficient curing
- Using excessive vibration near the mould

Possible Precautions:
- Changing the concrete contact surface of the mould
- Improving curing and polishing

Comment:
Cracks appear in the form of a map. Appearance typically improves over time. Rarely becomes more than an aesthetic problem.

Thin Surface Cracks (J-K)

Formation Time: Longer than 2 years

Formation Frequency: Mostly on old concrete

Most Seen On

Columns and Beams (L), Precast Concrete (M), Concrete Exposed to Freezing - Thawing or Sea Salts (M

Main Causes:
- Concrete Cover Insufficiencies (L)
- Excess calcium chloride (M)
- Chloride transitions (M)

Secondary Causes:
- Unsuitable concrete class (permeable)
- Insufficient curing
- Insufficient compacting

Possible Precautions:
- Increasing concrete cover
- Higher class concrete
- Good compaction
- Good curing
- Using chloride-free accelerator
- Possibility of repair by specialists

Comment:
Reinforcement corrodes and cracks the concrete. Rust stains typically appear in cracks.

Alkaline Silica Reaction (N)

Formation Time: Longer than 5 years

Formation Frequency: Very Rare

Most Seen On

Wet Areas

Main Causes:
- Alkalis in the cement form a water-absorbing and expanding gel by interacting with the reactive components of the aggregate in the presence of water.

Possible Precautions:
- Consulting the concrete manufacturer (impossible to repair, but not as important as it seems).

Comment:
Cracks appear in the form of a map. Sometimes a white colored gel forms inside the cracks.

Early Freezing Damage (P)

Formation Time: 1 - 24 hours

Formation Frequency: Very Frequently

Most Seen On

Thin Sections, Slabs

Main Causes:
- Freezing and expansion of water in fresh concrete

Secondary Causes:
- Failure to comply with curing and insulation requirements.

Possible Precautions:
- Maintaining the concrete temperature over +5°C until the end of the curing procedure
- Insulating

Comment:
Concrete damaged by freezing has no structural strength. Such concrete must be replaced.

Alkaline Silica Reaction (N)

Formation Time: Beton Sertleştikten Sonra

Formation Frequency: Very Frequently

Most Seen On

Flooring

Main Causes:
- Freezing water seeps through the surface of hardened concrete and expands, causing the surface to crack and crumble.

Secondary Causes:
- Unsuitable concrete class and type
- Insufficient curing

Possible Precautions:
- Using high quality and air entraining concrete
- Sufficient curing

Comment:
Deicing salts worsen the situation.

Structural Cracks

These cracks are caused by stress the structure is required to withstand due to its intended use. They occur in structures with poor soil bearing and due to faulty construction practices and are extremely dangerous; they are not related to concrete pouring and casting conditions. Engineering offices, universities and similar competent authorities should be consulted in such cases. Such issues do not occur as long as the structure is designed properly and there is no overloading. Structural cracks occur perpendicular to the tensile stresses in the reinforced concrete component. Cracks that occur in the center of a simple beam span or on a bracket support are of this type.

Cracks Caused by Application

These cracks appear on fresh or old concrete.

Fresh Concrete Cracks

Fresh concrete cracks occur during the first 30 minutes to 5 hours of the placement of concrete into the mould, usually on concretes applied to large surfaces such as slabs. These cracks can be as deep as 2 cm and as long as a few centimeters to 2 meters. Deep and long cracks can be very detrimental to the strength and durability of the concrete. Two particularly important causes for fresh concrete cracks are settling and plastic shrinkage.

Settling Cracks

These cracks occur on freshly cast, uncovered, uncured concrete with excessive water content, hollow reinforced concrete elements, areas with excess reinforcement, in cases of incorrect concrete placement, just above the reinforcements close to the top surface. Coarse aggregate grains sink to the bottom while water containing cement particles rises to the surface in fresh concrete. Beam and slab reinforcements that are close to the surface resist this displacement, so fresh concrete fails to settle in such areas properly. Unsettled concrete form cracks along the bar. As slabs are thin components, settling duration is minimal cracks are not commonly observed. Since beams are located deeper, settling duration might be significant and cracks occur along the bars. So, cracks reveal the location of the reinforcement. Settling duration increases as the water content of the concrete increases. Settling duration increases also if the concrete is not placed, compacted, and vibrated properly. So does cracking. This can be avoided by using concrete with a slump of -12 cm at normal consistency, avoiding using concretes having high consistency and high water content, and properly vibrating the concrete.

Plastic Shrinkage Cracks

These are randomly distributed cracks of varying length and width, typically found in concrete slabs, flooring, roads, tracks cast in hot, dry, and windy weather. These are generally shallow surface cracks with width smaller than 1 mm, and do not pose a threat to the safety of the structure.

When the concrete slab is cast, the surface water begins to evaporate, and water contained in the concrete comes up towards to surface (bleeding). If the rate of evaporation is higher than the rate of bleeding, the surface of the concrete begins to dry, shrink, and crack. Same cracks can also be caused by old, dry concrete underneath the newly poured concrete, or by other materials such as briquettes in hollow decks absorbing concrete water.

Factors that Increase the Evaporation Rate

Air Temperature: Evaporation increases as air temperature increases. An increase in temperature of 10°C approximately doubles the rate of evaporation. Evaporation is accelerated if the temperature of the concrete is higher than that of the air.

Air Humidity: Evaporation becomes faster and easier as the air humidity decreases (dry air). A decrease of relative humidity from 90% to 5% increases evaporation five times.

Wind Speed: Evaporation rate increases as the wind speed increases. An increase of wind speed from 0 to 20 km increases evaporation four times.

Sunlight: As the surface temperature of concrete exposed to sunlight increases and evaporation accelerates.

Two main reasons that affect the water bleeding rate of concrete is its compactness and aggregate granulometry. Less void in the granulometry of the aggregate means higher concrete strength, but it becomes harder and takes longer for the water to rise to the surface if there are no voids. When the evaporated water cannot be replaced by bleeding water, the surface of the concrete becomes dry and cracks. As the granulometry of the ready mixed concrete is well-adjusted, water bleeding becomes difficult, which increases plastic shrinkage cracks.

Precautions to Minimize Plastic Shrinkage and Related Cracks:

- Dampen the mould the concrete will be cast and the ironwork of the reinforcement to prevent the mould elements from absorbing water from concrete accelerate its drying.
- Avoid exposing the concrete to sunlight (by providing shade or casting at night), heat (by casting at night) and wind (with a windbreak).
- Prevent the evaporation of water by wrapping the concrete in wet sacks or nylon covers. You can also prevent evaporation by applying or spraying curing material.
- Working with a sufficient number of skilled workers, cast the concrete quickly, level it and proceed curing. Maintain curing for at least 3 days.

Plastic shrinkage cracks can occur within 35-40 minutes, long before concreting procedure is completed. It may therefore be necessary to take precautions to protect the finished sections during concreting. These precautions can be gradually taken by covering the leveled areas with nylon or damp cloth and applying a curing material. If no precautions are taken, concrete cracks more or less depending on its temperature, air humidity and wind speed. It is in your hands to minimize the number of cracks.

Old Concrete Cracks

These cracks can be seen in concrete of age groups from a couple of weeks to 30 years. They may be physical or chemical in nature. They first appear very thin, and in time they grow and merge. Flaking, spalling, and bursting can be observed on the surface of the concrete following the formation of the cracks. Reinforced concrete component can be completely damaged over time if precautions are not taken.

The causes of these cracks include freezing - thawing, alkali activated silica reaction, carbonation, corrosion of reinforcement, reactions caused by substances harmful to concrete such as sulphate, acid, and salt.

Table 1: 27 Cements of Common Cement Class

Cement Type	Name	Notation	Main Components (% by mass)										Minor Additional Components
			Klinker K	Blast Furnace Slag S	Silica Fume D	Natural Pozzolan P	Industrial Pozzolan Q	Siliceous Fly Ash V	Calcareous Fly Ash W	Baked Schist T	Chalk (Limestone) L	Chalk (Limestone) LL	
CEM I	Portland Cement	CEM I	95-100	–	–	–	–	–	–	–	–	–	0-5
CEM II	Portland Slag Cement	CEM II/A-S	80-94	6-20	–	–	–	–	–	–	–	–	0-5
		CEM II/B-S	65-79	21-35	–	–	–	–	–	–	–	–	0-5
	Portland Silica Fume Cement	CEM II/A-D	90-94	–	6-10	–	–	–	–	–	–	–	0-5
	Portland Pozzolan Cement	CEM II/A-P	80-94	–	–	6-20	–	–	–	–	–	–	0-5
		CEM II/B-P	65-79	–	–	21-35	–	–	–	–	–	–	0-5
		CEM II/A-Q	80-94	–	–	–	–	–	–	–	–	–	0-5
		CEM II/B-Q	65-79	–	–	–	–	–	–	–	–	–	0-5
	Portland Fly Ash Cement	CEM II/A-V	80-94	–	–	–	–	6-20	–	–	–	–	0-5
		CEM II/B-V	65-79	–	–	–	–	21-35	–	–	–	–	0-5
		CEM II/A-W	80-94	–	–	–	–	–	6-20	–	–	–	0-5
		CEM II/B-W	65-79	–	–	–	–	–	21-35	–	–	–	0-5
	Portland Baked Schist Cement	CEM II/A-T	80-94	–	–	–	–	–	–	6-20	–	–	0-5
		CEM II/B-T	65-79	–	–	–	–	–	–	21-35	–	–	0-5
	Portland Limestone Cement	CEM II/A-L	80-94	–	–	–	–	–	–	–	6-20	–	0-5
		CEM II/B-L	65-79	–	–	–	–	–	–	–	21-35	–	0-5
		CEM II/A-LL	80-94	–	–	–	–	–	–	–	–	6-20	0-5
		CEM II/B-LL	65-79	–	–	–	–	–	–	–	–	21-35	0-5
	Portland Composite Cement	CEM II/A-M	80-94	12-20									0-5
		CEM II/B-M	65-79	21-35									0-5
CEM III	Blast Furnace Slag Cement	CEM III/A	35-64	36-65	–	–	–	–	–	–	–	–	0-5
		CEM III/B	20-34	66-80	–	–	–	–	–	–	–	–	0-5
		CEM III/C	5-19	81-95	–	–	–	–	–	–	–	–	0-5
CEM IV	Pozzolanic Cement	CEM IV/A	65-89		11-35								0-5
		CEM IV/8	45-64		36-55								0-5
CEM V	Composite Cement	CEM V/A	40-64	18-30	–	18-30			–	–	–	–	0-5
		CEM V/8	20-38	31-49	–	31-49			–	–	–	–	0-5

Table 2: Cement Classes and Strengths TS EN 206-1

Compressive Strength Class	Minimum Characteristic Cylinder Strength fck,cyl (N/mm²)	Minimum Characteristic Cube Strength fck.cube (N/mm²)
C 8/10	8	10
C 12/15	12	15
C 16/20	16	20
C 20/25	20	25
C 25/30	25	30
C 30/37	30	37
C 35/45	35	45
C 40/50	40	50
C 45/55	45	55
C 50/60	50	60
C 55/67	55	67
C 60/75	60	75
C 70/85	70	85
C 80/95	80	95
C 90/105	90	105
C 100/115	100	115

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