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Analysis of Compressive Strength of Concrete at Different Water Cement Ratio

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Abstract—*Concrete has been used for construction in various ancient civilizations. Concrete is used to make pavements, pipe, architectural structures, foundations, motorways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles. Concrete is used more than any other man-made material in the world.*
In this research paper it is conclude that when the w/c ratio increases, the strength of concrete decreases and as the time period of curing is increasing the strength of concrete is increasing. So better curing and water cement ratio gives us a good and strength of concrete

Keywords*: cement concrete, water cement ratio, compressive strength.*

1. INTRODUCTION

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementatious materials such as fly ash. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds with the other components together, eventually creating a robust stone-like material. Concrete is used to make pavements, pipe, architectural structures, foundations and motorways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles.

Fresh concrete is that stage of concrete in which concrete can be molded and it is in plastic state. This is also called "Green Concrete". Another term used to describe the state of fresh concrete is consistence, which is the ease with concrete will flow. The hardening of concrete before its hydration is known as setting of concrete. Setting of concrete is based or related to the setting of cement paste. Thus cement properties greatly affect the setting time. There are various factors which affecting the setting of concrete such as Water cement ratio, Temperature, Cement content, Fineness of Cement, Relative Humidity etc. Bleeding rate of cement increases with time up to about one hour or so and thereafter the rate decreases but continues more or less till the final setting time of cement.

2. CEMENT CONCRETE

There are various properties of cement concrete such as Strength of concrete, Concrete Creep, Shrinkage, Modulus of Elasticity, Water tightness (impermeability) and Rate of Strength gain of Concrete.

The strength of concrete is basically referred to compressive strength and it depends upon three factors which are Paste Strength, Interfacial Bonding and Aggregate Strength.

2.1 Rate of Strength Gain of Concrete

Strength can be defined as ability to resist change. One of the most valuable properties of the concrete is its strength. Strength is most important parameter that gives the picture of overall quality of concrete. Strength of concrete usually directly related to cement paste. Many factors influence the rate at which the strength of concrete increases after mixing.

2.2 Materials Used In Cement Concrete

Portland cement is the single most commonly used building material in the world today. The use of natural cement, consisting of mixtures of lime and clay (aluminium) silicates), emerged in England in the late 18th century Joseph Aspdin obtained the first patent on cement manufacture in 1824. Aspdin carefully proportioned amounts of lime and clay, then pulverized the mixture and burned it in a furnace. He named his mixture Portland cement, because the colour of the powder resembled the colour of the rock quarries on the Isle of Portland.

2.3 Tests on Cement

Checking of materials is an essential part of civil engineering as the life of structure is dependent on the quality of material used. Following are the tests to be conducted to judge the quality of cement.

2.3.1 Fineness test

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength. In commercial cement it is suggested that there should be about 25-30 per cent of particles of less than 7µm in size.

2.3.2 Soundness test

It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The testing of soundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln.

2.3.3 Consistency test

The standard consistency of a cement paste is defined at that consistency which will permit a Vicat plunger having 10mm diameter and 50mm length to penetrate to a depth of 33-35 mm from the top of the mould shown in figure. The appartus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The percentage by weight of water respect to produced standard consistency is 32.33%. Standard consistency of cement according to IS: 8042-1989 is 30%

2.3.4 Sieve Analysis

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I)- 1963. In this we use different sieves as standardized by the IS code and then pass aggregates though them and thus collect different size particles left over different sieves. The apparatus used are –

i. A set of IS Sieves of sizes -80mm, 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm, 4.75mm, 3.35mm, 2.36mm, 1.18mm

ii. Balance or scale with an accuracy to measure 0.1 percent of the weight of the test samples.

2.3.5 Aggregate Impact Value

This test is done to determine the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV)–1963. The apparatus used for determining aggregate impact value of coarse aggregates is Impact testing machine conforming to IS: 2386 (Part IV)- 1963,IS Sieves of sizes–12.5mm, 10mm and 2.36mm, A cylindrical metal measure of 75mm dia. and 50mm depth, A tamping rod of 10mm circular cross section and 230mm length, rounded at one end and Oven. The impact value of aggregate specimen is 20.60

2.3.6 Aggregate Abrasion Value

This test helps to determine the abrasion value of coarse aggregates as per IS : 2386 (Part IV)–1963. The apparatus used in this test are Los Angles abrasion testing machine, IS Sieve of size–1.7mm, Abrasive charge–12 nos. cast iron or steel spheres approximately 48mm, die and each weighing between 390 and 445g ensuring that the total weight of charge is 5000 + 25gm and oven.

2.3.7 Aggregate Crushing Value

This test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386 (Part IV)–1963. The apparatus used is cylindrical measure and plunger, Compression testing machine, IS Sieves of Sizes–12.5mm, 10mm and 2.36mm. The crushing value of aggregate is 20.72% .

3. MIXING OF CONCRETE

Thorugh mixing is essential for the production of uniform, high quality concrete. Therefore, equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work. The two methods used in mixing concrete are hand mixing and concrete mixer.

3.1 CONCRETE MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job.

3.2 Requirements of concrete mix design

The requirements which form the basis of selection and proportioning of mix ingredients are :

i. The minimum compressive strength required from structural consideration.
ii. The adequate workability necessary for full compaction with the compacting equipment available.
iii. Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions.
iv. Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20 M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1:5:3) and (1:1:2) respectively.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm$^{2.}$ No control testing is necessary reliance being placed on the masses of the ingredients.

3.3 Factors affecting the choice of mix proportions

- Compressive strength is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. According to Abraham's law the strength of fully compacted concrete is inversely proportional to the water-cement ration.
- The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort.
- The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete.
- Maximum nominal size of aggregate as per IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.
- Quality Control

3.4 Mix Proportion Designations

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass.

3.5 Procedure

Compressive strength at 28-day f_{ck} and the level of quality control.

$\boldsymbol{\sigma_t} = f_{ck} + 1.65\ \sigma$.

Where σ is the standard deviation obtained from the Table of approximate contents given after the design mix.

1. Obtain the water cement ratio for the desired mean target using the empirical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
2. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.
3. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.
4. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
5. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
6. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
7. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations :

$$V = \left[w + \frac{C}{S_c} + \frac{1}{p}\,\frac{f_a}{s_{fa}} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\,\frac{C_a}{S_{ca}} \right] \times \frac{1}{1000}$$

Where

V = absolute volume of concrete minus the volume of entrapped air

w = gross volume ($1m^3$)

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

f_a, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively.

1. Determine the concrete mix proportions for the first trial mix.
2. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.
3. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

Design a concrete mix for use in plain concrete from the following data

1. Characteristic strength of concrete = 20 N/mm^2 and $25N/mm^2$@28 days.
2. Type of exposure condition = Severe
3. Type of Cement = 43 grade (Ordinary Portland Cement)
4. Fineness Modulus of : a. Coarse Aggregate = 6.7 b. Fine Aggregate = 2.2.
5. Voids in coarse and fine aggregate are 35% and 40% respectively
6. Density
7. Cement = 1500 kg/m^3 b. Fine Aggregate = 1700 kg/m^3 c. Coarse Aggregate = 1600 kg/m^3
8. Specific Gravity :- a. Coarse Aggregate = 2.7 b. Fine Aggregate = 2.65

4. PREPRATION OF CONCRETE CUBES

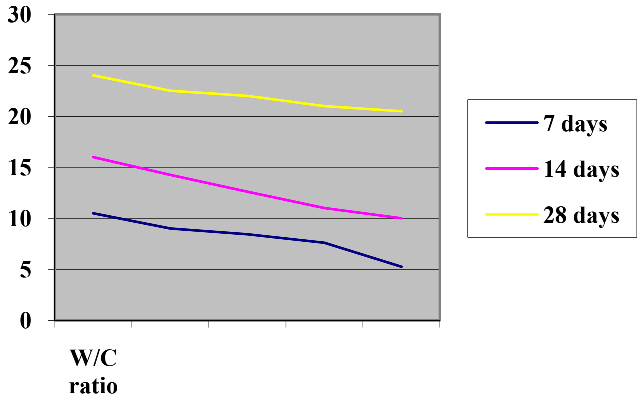
Concrete cubes are made on site to check that the strength of the concrete is above the minimum strength which has been specified. Making, curing and testing cubes should be carried out in the correct manner. Even small deviations from the standard procedures will usually lead to compressive strength results which are lower than the true strength of the concrete. The standard size of cube is $150mm^3$. The mould for the specimens must be made of cast iron or cast steel. After the sample has been mixed, immediately fill the cube moulds and compact the concrete, either by hand or by vibration. Any air trapped in the concrete will reduce the strength of the cube. Hence, the cubes must be fully compacted. However, care must also be taken not to over compact the concrete as this may cause segregation of the aggregates and cement paste in the mix. This may also reduce the final compressive strength. 150 mm moulds should be filled in three approximately equal layers (50 mm deep). During the compaction of the first layer, the compacting bar should not forcibly strike the bottom of the mould. For subsequent layers, the compacting bar should pass into the layer immediately below. The minimum number of strokes per layer required to produce full compaction will depend upon the workability of the concrete, but at least 35 strokes will be necessary except in the case of very high workability concrete. After the top layer has been compacted, a trowel should be used to finish off the surface level with the top of the mould, and the outside of the mould should be wiped clean. Immediately after curing, the cubes should be covered with damp matting or other suitable damp material and then with polythene or similar impervious sheeting and stored in a place where the temperature can be kept at 27 + 5°C for approximately 16 to 24 hrs. Test cubes should be demoulded between 16 and 24 hours after they have been made. If after this period of time the concrete has not achieved sufficient strength to enable demoulding without damaging the cube then the demoulding should be delayed for a further 24 hours. Take care not to damage the cube because, if any cracking is caused, the compressive strength may be reduced. After demoulding, each cube should be marked with a legible identification on the top or bottom using a waterproof crayon or ink.

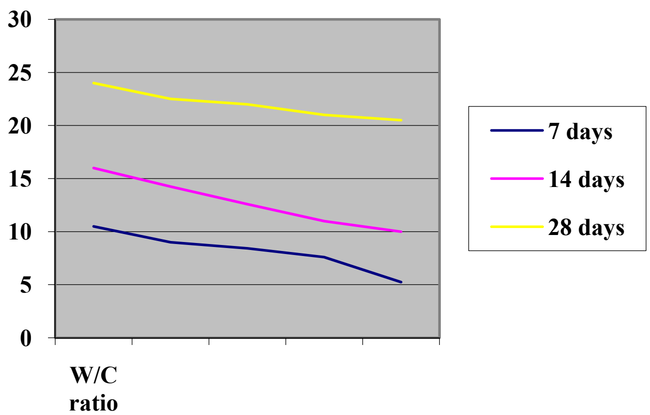
5. RESULT & DISCUSSION

Specimen is centrally placed on the testing machine, then we apply load on the specimen at the rate of 4 t/m till the specimen Reaches at failure. Due to compression load the cube undergoes lateral expansion owing to the poisson's ratio effect. The steel plates do not undergo lateral expansion to the some extent that of concrete with the result that steel restrains the expansion tendency of concrete in the lateral direction. This induces the tangential force between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine. It has been found that lateral strain in the steel plates is only 0.4 of the lateral strain in the concrete. Due to this the platen restrain the lateral expansion of the concrete in the specimen near its end the degree of restrain exercised depends on the friction actually developed.

Table 1: Compressive Strength of cubes (N/mm2)

W/C	7 DAYS		14 DAYS		28 DAYS	
	M20	M25	M20	M25	M20	M25
0.40	10.50	10.50	16.00	16.00	19.00	24.00
0.45	9.00	9.00	14.25	14.25	18.50	22.50
0.50	8.44	8.44	12.60	12.60	18.00	22.00
0.55	7.60	7.60	11.00	11.00	17.50	21.00
0.60	5.25	5.25	10.00	10.00	17.	20.50





Different Water Cement Ratio

M20 (1:1½:3)- 26 to 30 lit(Water),Cement - 404kgs

M25 (1:1:2) - 21 to 27 lit(Water),Cement - 563kgs

6. CONCLUSION

With the help of curve (between compressive strength of concrete & W/C ratio) it is observed that when the w/c ratio increases, the strength of concrete decreases. We also conclude that when we are using admixture than the strength of the concrete is increasing in same w/c ratio. As the time period of curing is increasing the strength of concrete is increasing, as our cubes of 7 days curing fail's in less crushing strength in comparison to the 14 days and 28 days. So better curing and water cement ratio gives us a good and strength of concrete.

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