Design and Development of M150 Grade Concrete

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***Abstract:*-Concrete is easy to work with, versatile, durable, and economical. By taking a few basic precautions, it is also one of the safest building materials known. The use of high strength concrete results in many advantages such as reduction in beam and column sizes and increase in the building height with many stories. High strength concrete is usually considered to be a concrete with 28 days compressive strength of at least 40 MPa. But in recent years, it is defined as the concrete having a minimum 28 days compressive strength of 60 MPa. In many developed countries, the concrete producers arbitrarily having 28 days compressive strength of above 45 MPa when normal weight of aggregate is used. High strength concrete has been widely used in Civil Engineering in recent years. High strength is made possible by reducing porosity, non homogeneity and micro cracks in concrete and the transition zone. It can be achieved by using super plasticizers and supplementary cementing materials such as silica fume, granulated blast furnace slag and natural pozzolana. High strength concrete has a high modulus of elasticity. High performance concrete with a very low permeability ensures long life of structure exposed to such conditions. The durability is not a problem under extreme conditions of exposure. Preliminary experiments have been done on Cement, Fine aggregate and Coarse aggregate. In the present investigation, Silica fume is used as mineral admixture and 920SH is used as chemical admixture. The w/c ratio for M150 concrete is considered as 0.25. By following the design procedure given by ACI Method, the mix Proportion for M150 grade concrete is derived as 1 : 0.454 : 1.527. The compressive and split tensile strengths are identified for the concrete after exposed to elevated temperature ranging from 50 to 250°C with the exposure duration of 1 to 4 hours.**

***Keywords:* High strength concrete, Silica fume, Pozzolana, Mineral admixture, Chemical admixture**

I. INTRODUCTION

Concrete is a product obtained by hardening of the mixture of cement, sand, gravel and water in predetermined operations. Concrete is one of the most widely used construction materials throughout the world. Many desirable properties such as high compressive strength, excellent durability and fire resistance contributed toward its wide range of applicability. The most advantageous and unique feature of concrete is that it can be produced using locally available ingredients as aggregates. Therefore, in countries where steel is not readily available, as in Bangladesh, concrete is the most used construction material. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the require quality performance or durability. In such cases, Admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

1.1. High Strength Concrete

In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure.

1.2. Admixtures

Admixture is defined as a material, other than cement, water and aggregates which is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Additive is material, which is added at the time of grinding cement clinker at the cement factory. It will be slightly difficult to predict the effect and the results of using admixtures because, many a time the change in the brand of cement, aggregate grading mix proportions and richness of mix after the properties of concrete. Sometimes many admixtures affect more than one property of concrete. Some times more than one admixture is used in the same mix. The effect of more than one admixture is difficult to predict. Therefore, one must be cautious in the selection of admixtures and in predicting the effect of the same in concrete.

For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

1.2.1. Silica fume

Silica fume is one of the mineral admixtures. It is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

1.2.2. 920SH

920 SH is a chloride free, super plasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. 920SH disperses the fine particles in the concrete mix, enabling the water content of the concrete perform more effectively. The very high levels of water reduction is possible by allowing major increase in strength to be obtained.

II. LITERATURE REVIEW

The following literature gives an idea on various design codes used for design mix proportioning of high strength concrete and the advantages for the use high strength concrete.

i. ***Mohamed bhai (1986)*** **[1]** carried out tests on 100 mm concrete cubes heated to temperatures in the range of 200-800^{o}C, to determine the effect of varying time of exposure and rates of heating and cooling on the residual compressive strength of concrete. These variables were found to have a significant effect on concrete heated to the lower range of temperatures, but their effect became less pronounced at high temperatures. It was reported that almost all the loss of compressive strength occurred within two hours of exposure to the maximum temperature. It was observed that the exposure time beyond one hour had a significant effect on the residual strength of concrete, but the effect diminished as the level of exposure temperature increased, where as the loss of strength in bulk occurred within first two hours of exposure. It was also observed that the effect of exposure time on coral-sand concrete is similar to that on basalt-sand concrete. It was also noticed that the rates of heating and cooling had no effect on the residual compressive strength of concrete heated to lower temperature.

ii. ***Srinivasa Rao et al (2006)*** studied the effect of elevated temperatures on c**o**mpressive strength of concrete. In this study, M60 grade of concrete was generated with water cement ratio 0.25 using Ordinary Portland Cement of 53 grade. Part of the cement is replaced with flyash. At different ages of 1, 3, 7, 28, 56 and 91 days of curing, the compressive strength of concrete is obtained after exposed to temperatures 50-250oC for 3 hours duration. The size of the concrete specimen is 100 mm. The rate of heating is maintained as 1oC/min and the specimens are tested in hot condition. From the test results it is concluded that retention of residual compressive strength is more in PPC than OPC. The residual strengths decreased as the temperature increased at different ages. For earlier ages the decrease in strength is 10 to 30% for OPC and PPC concrete with exposure duration, 3 hours. At 250oC, the maximum decrease in strength for OPC concrete is 40% and for PPC, it is 18%. As age of concrete increased, residual compressive strength increased.

iii. ***Khan and Abbas (2015)*** studied the behavior of high volume fly ash concrete at varying peak temperatures. Concrete cylinders of 100 × 200 mm were prepared by replacing the cement with fly ash in the range of 40-60% by weight. These concrete specimens, after 28 days curing, were exposed to varying peak temperatures ranging from 100 to 900oC to investigate the influence of temperature on the behavior of fly ash concrete. The compressive and split tensile strength of concrete increased initially with an increase in the temperature up to 300oC, however, further increase in the exposure temperature caused reduction in both strengths. The loss of weight of the concrete increased with increase in the temperature as well as the fly ash content.

iv. ***Muhammad Masood Rafi et al (2017)*** Conducted experimental testing programme on cylindrical specimens of 100 × 200 mm size. They were heated at temperatures which were varied from 100°C to 900°C in increment of 100°C. Similar specimens were tested at ambient temperature as control specimens. The compressive and tensile properties of heat treated specimens were determined. The colour of concrete started to change at 300°C and hairline cracks appeared at 400°C. Explosive spalling was observed in few specimens in the temperature range of 400°C-650°C which could be attributed to the pore pressure generated by steam. Significant loss of concrete compressive strength occurred on heating temperatures larger than 600°C, and the residual compressive strength was found to be 15 per cent at 900°C. Residual tensile strength of concrete became less than 10 per cent at 900°C. The loss of concrete stiffness reached 85 per cent at 600°C. Residual Poisson's ratio of concrete increased at high temperatures and became nearly six times larger at 900°C as compared to that at ambient temperature.

III. MIX DESIGN PROCEDURE

The ACI Standard 211.4 code "*Guide for selecting proportions for High-Strength Concrete with Portland cement and Flyash*" is used for mix design

3.1.1 Design Stipulations

Grade of concrete	: M150
Size of aggregate	: 10 mm
Degree of workability	: 0.76 (compaction factor)
Degree of quality control	: good
Type of exposure	: moderate
Cement	: Portland Pozzolana Cement (PPC)

3.1.2 Test Data for Materials

Specific gravity of cement	: 3.15
Specific gravity of fine aggregate	: 2.68
Specific gravity of coarse aggregate	: 2.72

Water absorption of fine aggregate : 1.2%

Water absorption of coarse aggregate : 0.8%

Bulk Density of coarse aggregate : 1720 kg/m^3

Aggregate Impact value : 8.4% (Exceptionally Strong)

3.1.3 Sieve Analysis

Fine aggregate : Sand zone II according to IS: 383 -1970

Coarse aggregate : Confirming to IS: 383 -1970

Trial strength

f_{cr} = Trial Mix Strength

f_{ck}= Specified Compressive Characteristic Strength = 150 N/mm^2

S = Standard deviation (from ACI 211.4) =10

1) $f_{cr}= f_{ck}+1.34*S = 150 + 1.34*10=163.4$ N/mm^2
   Or
2) $f_{cr}= 0.9*f_{ck}+2.33*S=0.9*150+ 2.33*10=158.3$ N/mm^2

Larger Value out of these two is taken as f_{cr}

Therefore, the Value of f_{cr} = 163.4 N/mm^2

Step-1 Choice of slump

The value of slump height is taken from the table 4.3.1 of ACI 211.4R based on the type of work. Slump Height is considered as 50 mm.

Step-2 Choice of maximum size of aggregate

The ACI method is based on the principle that the Maximum size of aggregate should be the largest available so long it is consistent with the dimensions of the structure.

When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate as they produce higher strengths at a given w/c ratio. The maximum size of Coarse aggregate is taken as 10 mm from the Table 4.3.2 of ACI 211.4R code.

Step-3 Estimation of mixing water and air content

From the Table 4.3.4 of ACI 211.4R, the quantity of water required (for 50 mm Slump and 10 mm aggregates) = 183 kg/m^3

Step-4 Selection of water/cement ratio

Let the water/cement ratio = 0.25

Step-5 Calculation of cement content

Water/cement ratio = 0.25 & Water content = 183 kg/m^3 & Specific gravity = 3.15

=> Cement content = 183 / 0.25

= 732 kg

Step-6 Estimation of coarse aggregate content

From the Table 4.3.3 of ACI 211.4R, the volume of oven dry rodded coarse aggregate per unit of volume of concrete = 0.65 for 10 mm aggregate with fineness modulus of fine aggregate as 2.68.

Bulk Density of Coarse aggregate = 1720 kg/m^3

Per 1m^3 of Concrete, the Volume of C.A = 0.65 m^3

The quantity of C.A = 1720*0.65 = 1118 kg

Step-7 Estimation of Fine Aggregate Content

Volume based calculation

Volume of water = 183/1000 = 0.183 m^3

Volume of Cement = 732 / (3.15*1000) = 0.232 m^3

Volume of Coarse aggregate

= 1118 / (2.72*1000) = 0.411 m^3

Volume of entrapped air = 0.05 m^3

Volume of Fine aggregate

= 1 - 0.183 - 0.232 - 0.411 - 0.05

= 0.124 m^3

Fine Aggregate Content = 0.124x2.68x1000

= 332.32 kg

Step-8 Adjustments for Aggregate Moisture

Aggregate quantities actually to be weighed out for the concrete must allow for moisture in the aggregates. Usually the air-dry condition for the coarse aggregate is close enough for use in laboratory, but the fine aggregate is often 2% or 3% above or below SSD.

This means that a correction must be made before a laboratory batch of concrete is made.

Step-9 Trial Batch Adjustments

The ACI method is written on the basis that a trial batch of concrete will be prepared in the laboratory, and adjusted to give the desired slump, freedom from segregation, finishability, unit weight, air content and strength.

Table 1: Mix Proportion of M150 Grade Concrete

Cement	Fine Aggregate	Coarse Aggregate	Water
732 kg	332.32 kg	1118 kg	183 kg
1	0.454	1.527	0.25

Water / Cement ratio = 0.25

IV. EXPERIMENTAL TEST RESULTS

By conducting the workability slump test, it is found that the amount of 920SH required for getting the slump height 50 mm = 2% (total weight)

4.1 Determination of Compressive Strength: The cubes of 100 mm size are used for measuring the compressive strength of M150 concrete.

S. No.	% of Silica Fume	% of 920SH	Average Compressive Strength (28 days) N/mm^2
1	0	2	122.65
2	5	2	133.42
3	10	2	145.19
4	15	2	152.06
5	20	2	147.15
6	25	2	139.30

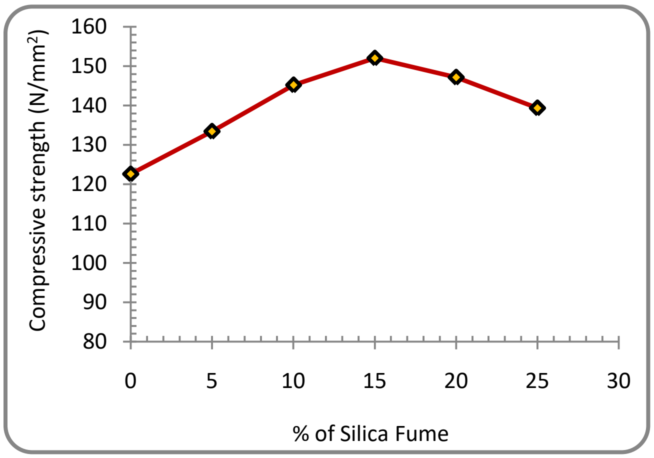

Fig 1: The graph shows the variation of 28 days compressive strength of concrete with the variation of % of silica fume.

V. CONCLUSIONS

1. The mix exhibited a slump of 70 mm with Chemical admixture (920SH) of 2% by weight of cement.
2. The mix proportion for M150 concrete by ACI method is derived as 1:0.454:1.527:0.25.
3. By maintaining the w/c ratio as 0.25, the 28 days compressive strength of the concrete is achieved as 152.06 N/mm^2 at 15% of silica fume and 2% of 920SH.

REFERENCES

[1]. Arshad, A. Khan, William, D. Cook and Denis Mitchel, “Tensile strength of low, medium and high strength concretes at early ages”, ACI Materials Journal, Sept-Oct 1996, pp. 487-493.

[2]. Eugen Brihwiler and Emmanuel Denarie (2008), “Rehabilitation of concrete structures using Ultra-High Performance Fibre Reinforced Concrete”, Department of civil Engineering, Lausanne, Switzerland.

[3]. Faghani Nobari, H., Ejlaly R., “Punching Shear Resistance of High Strength Concrete slabs”, Asian Journal of Civil Engineering (Building and Housing), Vol.4, No.1 (2003), pp. 55-63.

[4]. Flyod slate, O., Arthur Nilson H., and Salvador Martinez, “Mechanical properties of High strength Concrete”, ACI Journal, July-August 1986, pp. 606-613.

[5]. Gupta, S.M., Sehgal, V.K., Kaushik, S.K., “Study on Shrinkage of High Strength Concrete”, ACI Journal proceedings, 1884, Vol. 81, No.4 pp. 364-411.

[6]. Klaus Holschemacher, Sven Klotz (2003); “ Ultra High Strength Concrete under Concentrated Load”, Department of Civil Engineering, HTWK Leipzig.

[7]. Parrot, I.J (1969), “Properties of High Strength Concrete,” Technical Report No. 42.417, Cement and Concrete Association, Wexham Springs.

[8]. S.Nagataki and A.Yonekura (1978), “Studies of the Volume Changes of High Strength Concrete with Superplastizer,” Journal, Japan Prestressed Concrete Engineering Association Tokyo.

[9]. S.M.Gupta, V.K.Sehgal, S.K.Kaushik (1884); “Study on Shrinkage of High Strength Concrete”, ACI Journal proceedings Vol. 81, No.4 pp. 364-411.

[10]. Z. Wadud and S. Ahmad (2001); “ACI method of concrete mix design- A parametric study”, The Eighth East Asia-Pacific Conference on Structural Engineering and Construction, Nanyang Technological University, Singapore