Journal of Engineering Sciences
Vol 10, Issue 9, Sept /2019
ISSN NO:0377-9254

STUDY OF COST EFFECTIVENESS IN DESIGN OF STRUCTURES WITH HIGH PERFORMANCE CONCRETE

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ABSTRACT: High Performance Concrete May be considered as a logical improvement of cement concrete wherein the ingredients are proportioned and selected to make a contribution correctly to the numerous homes of cement concrete in clean as well as in hardened states. Higher electricity is one of the capabilities of High Performance Concrete which affords extensive structural advantages. The three principal components contributing to the cost of a structural member are concrete, metal reinforcement and formwork .This paper objectives at evaluating those essential additives while concrete of higher grade is used inside the design and to set up that High energy concrete gives the most not pricey way for designing the burden bearing participants and to hold a vertical load to the building foundation via columns. The mix layout variables affecting the concrete electricity which are the maximum important inside the electricity improvement of concrete includes watercementitious cloth ratio, general cementitious material, cement-admixture ratio, quantity of extraordinary plasticizer dose .These elements are to be analyzed a good way to acquire a mix for concrete of higher grade. The design resource presently available offers design charts for design of participants for concrete grade upto Fck=40N/mm².Design curves for Fy=250N/mm²,415N/mm² and Fck=60N/mm², Fck=70N/mm² the usage of MATLAB were drawn and given for assisting within the layout of structures designed with those better grade of concrete.

Key Words: High Performance Concrete, High Strength Concrete.

I. INTRODUCTION:

1.1 HIGH PERFORMANCE CONCRETE AND HIGH STRENGTH CONCRETE:

Concrete has been since long a major material for providing a stable and reliable infrastructure. Concrete with compressive strengths of 20-40 N/sqmm has been traditionally used in construction projects. With the demand for more sophisticated structural forms along with deterioration , long term poor performance of conventional concrete led to accelerated research for development of concrete which would score on all the aspects that a new construction material is evaluated upon : strength, workability, durability, affordability and will thus enable the construction of sustainable and economic buildings with an extraordinary slim design besides providing a material that will have long term better performance and reduced maintenance. The development of high performance concrete in this regard has been a great breakthrough in concrete technology. ACI defines High Performance Concrete as “Concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practices”.

Important governing factors for High Performance Concretes are strength, long term durability, serviceability as determined by crack and deflection control, as well as response to long term environmental effects. High performance concretes (HPC) are concretes with properties or attributes which satisfy the various performance criteria. Generally, concretes with higher strengths and attributes superior to conventional concretes are called High performance concrete. Therefore High Performance Concrete can be considered as a logical development of cement concrete in which the ingredients are proportioned and selected to contribute efficiently to the various properties of cement concrete in fresh as well as in hardened states. However, when 'high performance' is linked to structural significant behavior high performance is usually synonymous with high strength. Thus high strength concrete is basically a form of high performance concrete which has compressive strength higher than the conventional concrete. High strength concrete is specified where reduced weight is important or where architectural considerations require smaller load carrying elements .The use of high strength concrete offers 3 numerous advantages in the sustainable and economical design of structures and gives a direct savings in the concrete volume saved ,savings in real estate costs in congested areas, reduction in form-work area and cost.

POPULARISING THE DESIGN OF STRUCTURES USING High Performance Concrete:

The use of High Performance Concrete with significantly higher compressive strength of concrete is on increasing trend in the construction industry and is being seen as an optimized 4 solution considering the economics vis-à-vis strength and durability required for special structures. The scope of using High Performance Concrete in our constructional activities lies large, viz Multi-storied buildings, bridges and structures on coastal areas and the like. The primary reasons for selecting High Performance Concrete are to produce a more economical product, provide a feasible technical solution, or a combination of both. The use of HPC with its greater durability is likely to result in less maintenance and longer life and with the introduction of life-cycle costing, the long-term economic benefits are likely to more than offset the premium costs for initial construction. To affect this change from Conventional concrete to High Performance Concrete we will have to revive the designing of structures by encouraging use of High Performance Concrete by introducing the structural and economical advantages offered by High Performance Concrete.

II. LITERATURE REVIEW

The advantages of using High Performance Concrete particularly with the structural advantages of using high strength concrete have been described in various researches. These include a reduction in member size, reduction in the self-weight and super-imposed Dead Load with the accompanying saving due to smaller foundations, reduction in form-work area and cost construction of High–rise buildings with the accompanying savings in real estate costs in congested areas, longer spans and fewer beams for the same magnitude of loading, reduced axial shortening of compression supporting members ,reduction in the number of supports and the supporting foundations due to the increase in spans ,reduction in the thickness of floor slabs and supporting beam sections which are a major component of the weight and cost of the majority of structures, superior long term service performance under static, dynamic and fatigue loading, low creep and shrinkage . Achieving high strength concrete by using various chemical and mineral admixtures is also a subject of research and different design mix methods and trial mix approaches have been proposed for the development of high strength concrete. The various parameters that govern the strength of concrete like the different constituent materials required, properties of constituent materials , proportions in which they are to be used and specifications for the production and curing technique to be used for the development of high strength concrete are also being a subject of continuous research for the development of high strength concrete which is now being seen as a logical development of concrete because of the numerous advantages that it is supposed to provide.

2.1 SCOPE OF THE PRESENT WORK

The objective of the present work is to study the cost effectiveness of designing structures with High Performance Concrete by giving a cost comparison between concrete M20 and M60 using a concrete mix achieved in the laboratory .The effect of silica fume dosage and the dose of super plasticizer on the strength of concrete have been evaluated using an experimental programme aimed at achieving a High strength concrete mix. Design of a multi storied reinforced building has been done using both M20 and M60 using Staad Pro2004 and the differences in the quantity of concrete and steel required for different beams and columns have been calculated and analyzed and compared with respect to their cost.Design curves for M60 and M60 have also been generated using MATLAB and given in the report for use in design using the grades of concrete as the are not given in the design aid presently available.

III. ACHIEVING HIGH PERFORMANCE CONCRETE (HPC):

The development of High Performance Concrete is based on the following well known relationships of concrete technology, for high strength, water-cement ratio should be low. The strength - w/c ratio rule holds good for concrete strength of about 100 MPa or more. Low watercement ratio is also required for low permeability of concrete, which is vital for high durability. Impermeability is also aided by pore filling effects of fine pozzolanic additions. The relationship between coefficient of permeability of cement paste and water-cement ratio is such that the permeability increases asymptotically for water-cement ratio above 0.45 or so. Thus, low watercement ratio ensures both high strength and low permeability, or high durability. Low watercement ratio will require high cement content to ensure that the amounts of water and cement paste are adequate for the workability of concrete. However, too high a cement content will cause high heat of hydration and increase cracking tendency. Hence, part of the cement is to be replaced by other cementitious materials like silica fume, fly ash or ground granulated slag, or combinations thereof. Use of low water cement ratio and other cementitious materials as silica fume etc. makes use of superplasticisers mandatory. Thus, the composition of High Performance Concrete is automatically chosen -cement, aggregates, water, superplasticisers, silica fume or fly ash or slag.

COMPONENT REQUIREMENTS FOR High Performance Concrete:

CEMENT: A high quality binder is necessary for High Performance Concrete. Cement that yields high compressive strength at the later stage is obviously preferable. The use of fine cementitious material, such as Microsilica or superfine fly ash, is useful as the fine particles grading would be extended; which would result in good filler action and reduced porosity. Furthermore, the Pozzolanic reaction with Portland cement would further strengthen the cement matrix and improve the bond strength between aggregates and the matrix. Since the cement content of high 11 strength concrete is unavoidably high, the heat of hydration resulting from the exothermic reaction of cement with water is high. Thus it would be advantageous to use an additional cement replacement material such as ground granulated blast furnace slag or fly ash both of which are available in the local market. Furthermore, the use of such cement replacements in addition to the use of Micro silica and/or super fine ash would improve the impermeability of concrete to chlorides and sulphates; thus, the durability especially in relation to steel reinforcement corrosion protection would be improved.

COARSE AGGREGATE: Since coarse aggregate forms the largest fraction of volume of concrete the characteristics of aggregates significantly influence the strength of concrete. The size of coarse aggregate plays an important role in determining the strength of concrete. In normal strength concrete, as size of coarse aggregate is increased, the water requirement is reduced. So the net effect is gain in strength. But in High Performance Concrete large size of coarse aggregate tend to reduce the strength .It may be attributed to smaller surface area available for bond. Cement-aggregate bond increases as aggregate particle shape changes from smooth and rounded to smooth and angular, and this must be considered for selecting the aggregate for High Performance Concrete. But trial mixtures will be the best predictor of performance. In making the trial mixtures it is important to select relatively hard and strong coarse aggregates that do not break during mixing.

FINE AGGREGATE: The shape and surface texture of fine aggregate has a greater influence on water demand of concrete than because fine aggregates contain a much higher surface area for a given weight. Rounded and smooth fine aggregate particles are better from the view point of workability than sharp and rough particles.

CHEMICAL ADMIXTURES: Water-cement ratio plays a vital role for achieving HPC. Reduction in water content increases the strength considerably. This can be achieved by using water reducing admixture or Super 12 plasticizer. The use of superplasticizer generally reduces the amount of water required by 15%- 40%. Super plasticizers are usually chemical compounds such as sulphonated melamine formaldehyde (SMF), sulphonated naphthalene formaldehyde (SNF), and Modified ligno sulshonates.SMF and SNF based admixtures are the most commonly used. They work by helping to disperse particles of cement when mixing water is added,which causes the cement paste to behave more like a fluid. This deflocculation of cement particles plasticize the paste to such a degree that these compounds are dubbed as "Superplasticizers".

MINERAL ADMIXTURES: These admixtures are generally natural or by product materials .These admixtures generally include fly ash, silica fume, ground granulated blast furnace slag. Fly ash is produced as a byproduct of combustion of pulverized coal in electric power generating plants. Silica fume is a byproduct resulting from the reduction of high purity quartz with coal in electric arc furnaces in the manufacture of silicon or ferrosilicon alloys. As the Portland cement in concrete begins to react chemically, it releases Calcium hydroxide. The silica fume reacts with this calcium hydroxide to form an additional binder called calcium silicate hydrate, which is very similar to calcium silicate hydrate formed by Portland cement. It is largely this additional binder that gives silica-fume concrete its improved hardened properties. The addition of silica fume also increases the cohesiveness, viscosity and water demand of fresh concrete. Bleeding is reduced ,allowing quicker finishing and less chance of porous transition zones between paste and aggregate.

3.1 EXPERIMENTAL PROGRAMME

The main aim of the Experimental Programme was to achieve a mix proportion for M60 in the laboratory that we can propose for further use and can be used to calculate cost aspect for the above grade of concrete. To get the control mix Entroy and Shackalock method was used. It was 13 designed for extremely low workability. To improve the strength and workability silica fume and super plasticizers were used in trial batches. Silica fume was replaced by 5%,10% and 15%.To each percentage of silica fume replacement, superplasticizers were added in dosages of 1%,1.25% and 1.5%.Coarse aggregate was divided into three parts one retained on 5mm sieve, second part retained on 8 mm sieve and third part retained on 10 mm sieve passing 15 mm sieve. The control mix proportion: 1 : 0.812 : 2.088 Fine

Journal of Engineering Sciences

Vol 10, Issue 9, Sept /2019

ISSN NO:0377-9254

aggregate /Total aggregate: 28% Water/binder ratio=0.3

3.2 MATERIAL PROPERTIES:

Material	Specific gravity (gm/cc)
Cement	3.00
Fine aggregate	2.41
Coarse aggregate	2.63

Table 3.1. Material properties

DETAILS OF MIX-1 (Ms5) :

In this mix 5% cement was replaced by silica fume keeping the water/binder ratio same and to this, super plasticizer dosages of 1%,1.25% and 1.5% were added and the mixes were named as Ms5/1,Ms5/2,Ms5/3 respectively. So in Ms5/1, Ms5/2, Ms5/3 except super plasticizer dose all other quantities remain the same.

Mix	Cement (in kg)	Silica Fume (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Super plasticizer (in kg)
Ms5/1	570.4	30.02	488.8	1257.5	6.02
Ms5/2	570.4	30.02	488.8	1257.5	7.5
Ms5/3	570.4	30.02	488.8	1257.5	9

Table3.2. Details of MIX 1(Ms5)

DETAILS OF MIX-2(Ms10):

In this mix 10% cement was replaced by silica fume keeping the water/binder ratio same and to this, super plasticizer dosages of 1%,1.25% and 1.5% were added and the mixes were named as Ms10/1, Ms10/2, Ms10/3 respectively. So in Ms10/1, Ms10/2, Ms10/3 except super plasticizer dose all other quantities remain the same.

Mix	Cement (in kg)	Silica Fume (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Super plasticizer (in kg)
Ms10/1	540.4	60.04	488.8	1257.5	6.02
Ms10/2	540.4	60.04	488.8	1257.5	7.5
Ms10/3	540.4	60.04	488.8	1257.5	9

Fig: Details of MIX 2(Ms10)

3.3 RESULTS :

Measurement of Slump:

Each batch of concrete was tested for consistency immediately after mixing, by slump test as per IS : 1199-1959. The slump measured is recorded in terms of millimeters of subsidence of the specimen during the test and the following values are recorded for different trial mixes

MIX	SLUMP VALUE (in mm)
Ms5/1	5
Ms5/2	10
Ms5/3	25
Ms10/1	4
Ms10/2	8
Ms10/3	15
Ms15/1	0
Ms15/2	3
Ms15/3	15

Fig: Slump Values in mm for different mixes

Measurement of Compressive Strength of concrete at 28 days:

Making and Curing of Compression test specimen: The compression test specimens are cast as per IS : 516 – 1959. It involves • Sampling of Materials • Preparation of Materials • Proportioning • Weighing • Mixing Concrete • Compacting • Curing

3.3.2.2.2 Test for compressive strength of concrete specimen: Compression Test specimens (150*150*150 mm) are cast using cubical moulds as per IS : 516 – 1959 and tested for compressive strength .Three samples for each batch were tested and the results obtained are as follows:

MIX	28 days compressive strength(N/sqmm)
Ms5/1	60.1
Ms5/2	54.3
Ms5/3	51.2
Ms10/1	45.4
Ms10/2	51.1
Ms10/3	51.8
Ms15/1	47.3
Ms15/2	41.9
Ms15/3	45.2

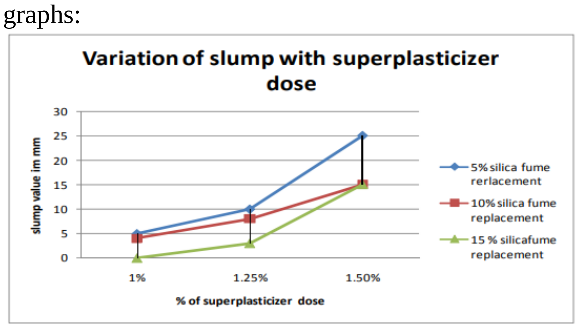
Table 3.7. Compressive strengths for MIX1,MIX2,MIX3

Mix	W/CM ratio	28 days compressive strength in N/sqmm
Ms10/1.25/0	0.3	51
Ms10/1.25/1	0.325	38.67
Ms10/1.25/2	0.35	37.33
Ms10/1.25/3	0.375	36.74

Table 3.8. Compressive strengths for MIX 4

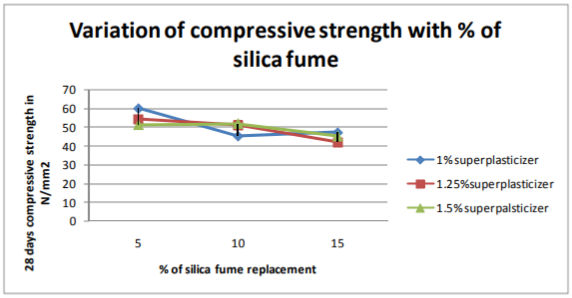
3.4 ANALYSIS OF RESULTS:

The variation of slump with superplasticizer content and the compressive strength variation with the silica fume replacement was observed with the following graphs:

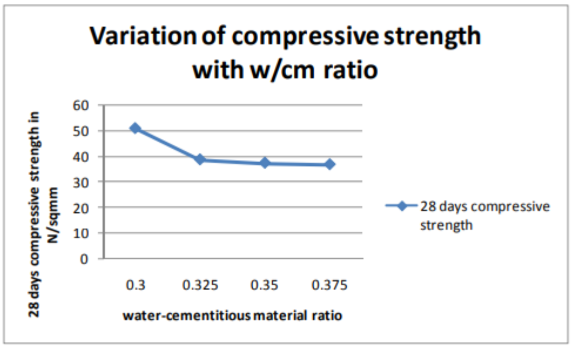


JES Journal of Engineering Sciences
Vol 10, Issue 9, Sept /2019
ISSN NO:0377-9254

Graph 3.1.Variation of Slump with Super plasticizer dose



Graph 3.2. Variation of compressive strength with % replacement of silica fume



Graph 3.3: Variation of compressive strength with W/CM ratio

IV. STUDY OF COST EFFECTIVENESS

4.1 COST CALCULATION AND COMPARISION FOR M20 AND M60:

The cost calculation for concrete M20 and M60 was done and found out to be:

Details of cost of 10 Cum of cement concrete(M60): 1: 0.812 : 2.088				
Materials	Unit	Quantity/Nos	Rate	Cost
Stone aggı	Cum	4.78	765.7	3660.046
sand	Cum	2.03	89.34	181.3602
cement	Quintal	57	360	20520
silica fume	kg	300.25	30	9007.5
Superplast	kg	60.24	50	3012
			Total cost per 10cum	36380.91
			Total cost per cum	3638.091

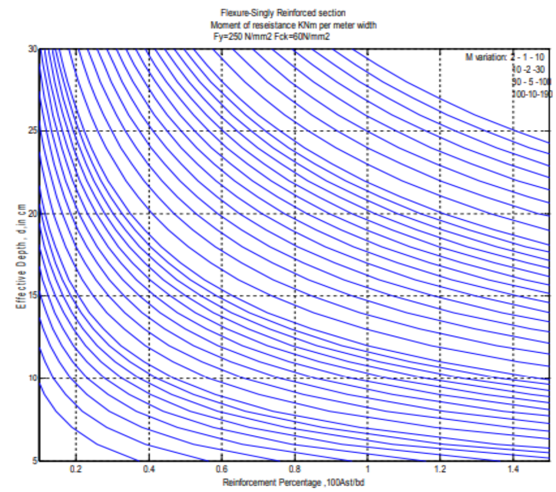
Table 4.1.Cost calculation for M60

Details of cost of 10 Cum of cement concrete(M20): 1:1.5:3				
Materials	Unit	Quantity/Nos	Rate	Cost
Stone aggı	Cum	8.52	765.7	6523.764
sand	Cum	4.41	89.34	393.9894
cement	Quintal	40	360	14400
			Total cost per 10 cum	21317.75
			Total cost per cum	2131.775

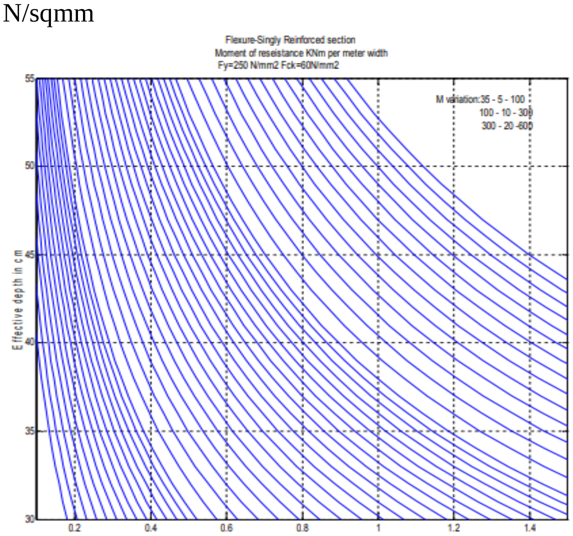
Table 4.2.Cost Calculation for M20

V. DESIGNING WITH High Performance Concrete(HPC):

“Design Aids For Reinforced Concrete to IS: 456-1978” play a very important role in designing the structural members. In currently available Design Aid for Flexural Members design curves for Fck=15N/mm² and Fck=20N/mm² are available .For popularising the use of M60 and M70 we have drawn the design curves for Fy=250N/mm²,415N/mm² and Fck=60N/mm²,Fck=70N/mm² using MATLAB. The design curves are prepared by assigning different values to Mu/b and plotting d versus Pt. The Design curves are given in the subsequent pages. In the graphs Moment of Resistance (M) variation has been shown on the right top corner. M variation:”2-1-10 “denotes the variation of M from 2 KNm to 10 KNm in steps of 1 KNm



Graph 5.1 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=60 N/sqmm



Graph 5.1 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=60 N/sqmm

VI. CONCLUSION

High Performance Concrete with higher compressive strength provides the most economical way for designing the load bearing members and to carry a vertical load to the building foundation through columns by a reduction in the quantity of steel required and also concrete which contribute mainly to the cost of the structural member. The mix design variables affecting the concrete strength which are the most critical in the strength development of concrete including water-cementitious material ratio, total cementitious material, cement-admixture ratio amount of super plasticizer dose are to be analyzed and optimum values of the critical mix design variables are to be taken for obtaining the mix design for the required High Performance Concrete.

RECOMMENDATIONS: The use of High Performance high strength concrete offers numerous advantages in the sustainable and economical design of structures and gives a direct savings in the concrete volume saved ,savings in real estate costs in congested areas, reduction in form-work area and. The use of High Performance Concrete with its greater durability is likely to result in less maintenance and longer life and with the introduction of life-cycle costing, the long-term economic benefits are likely to more than offset the premium costs for initial construction. To affect this change from Conventional concrete to High Performance Concrete we will have to revive the designing of structures by encouraging use of High Performance Concrete .

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