Critical review on Mix Proportioning stipulations for High Volume Fly ash concrete (HVFAC)

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Abstract - *Today's situation demands that concrete construction has to be eco-friendly as well as safe apart from being cost efficient so that society at large could be benefitted which makes large investments in the infrastructure projects. So, HVAFAC is widely used now a days as a replacement product to Portland cement which complies with the above statement. In this paper mix proportioning of high volume of fly ash concrete (HVFAC) is thoroughly studied from different research papers. Less water to binder ratio (w/b) plays an important role in mix proportioning. Fineness of fly ash is also an important aspect in this regard. The age factor also has a significant effect on high volume fly ash concrete, i.e. with the increase in number of days high volume fly ash concrete grabs more compressive strength.*

Key Words: **eco-friendly, cost efficient, Portland Cement, HVFAC, mix proportioning, age factor, w/b (water to binder ratio), fineness, compressive strength.**

1. INTRODUCTION

General

In recent scenario environmental friendly products are used. It is being tried by the researchers to make the concrete as environmental friendly as possible. So in this case HVFA (high volume fly ash) is used as an alternative to Portland Cement in high performance concrete mixtures. The use of ordinary portland cement is highly minimized with the use of high volume fly ash in concrete mixtures. The selection of mineral and chemical admixture should be done very judiciously to produce high performance concrete.

1.2 Mix proportioning

The process through which the correct combination of its ingredients is determined that is the resulting mix gives the desired characteristics with minimum cost is called mix proportioning. The process of proportioning of the constituents of concrete like cement, water, FA, CA, other SCMs and chemical admixtures is defined as mix-design. The quality of these constituent materials, water/ cement ratio and the mixing procedure plays a very important role in achieving the targeted strength and durability of the concrete mix, which finally controls the cost of the project. A To find the desired characteristics of concrete the mix proportions of concrete has to be more or less modified to establish the correct mix design. The proportioning of HPC involves proper procedure as summarized in the following steps:

1. Selection of materials: This involves selecting good quality, locally available constituent materials.

2. Mix-proportioning: This involves decision for mix-proportioning of selected materials from the available literature or guidelines.

3. Optimizing the materials: This involves optimizing the proportioning by using empirical or theoretical concepts.

4. Testing of sample: This involves finally evaluating the rheological properties and the mechanical properties of the optimized mix.

In making high performance or high strength concrete the constituents of high quality are used. These are very useful in obtaining the high strength of concrete. The constituents may comprises of a mixture of strong aggregate, a higher Portland cement content, low water/binder ratio, and selected admixture. Fly ash is a mineral admixture which is used in concrete, a by-product of coal-fired power stations. Fly ash as a replacement of cement has proven its acceptance and has given many advantages in the early and later stages of concrete after mixing. One of these advantages is that it is more durable than normal concrete. In the 1980s the term high volume fly ash was first used by Malhotra at CANMET, that is the maximum percentages of cement was replaced by fly ash which is above 50% came into the dictionary of concrete. Though high percentages of cement in high volume fly ash concrete is replaced by fly ash, it still gives high performance concrete. The particle size of fly ash is very influential in fly ash reactivity. One of the factors giving great influence in fly ash reactivity is the particle size. Generally fly ash particles ranging from 10 μm to 50μm act as void fillers in concrete, whereas smaller particles which are smaller than 10 microns are pozzolanic reactive.

2. MATERIALS

2.1 Fly ash

Fly ash is an environmental friendly product which is very useful in concrete. Since researchers are in great search to replace cement with an environmental friendly product, so fly ash is very much acceptable in this case. Fly ash almost has many similarities with that of cement. The size of fly ash also has a great impact in replacing cement. The sizes fly ash varies from 1 µm to 150 µm consisting of glassy spheres. The typical size of fly ash in particle size distribution is under 20 µm. The size of fly ash mainly depends on the source from where it is extracted and the equipment with which dust is collected. The use of a good fly ash affects the workability, durability, drying shrinkage, etc., that is, it greatly improves these mentioned conditions. The fly ash also helps in cost-cutting. The use of fly ash reduces the use of cement in concrete and hence reducing the cost. The thermal power stations also finds it difficult to dispose the waste material, so, utilising it contributes to the advantages of using fly ash.

2.2 Portland cement

Portland cement is the cement that is regularly used in our day to day construction. It is the most important constituent among all the constituents in mix proportioning of concrete. It is the binding material of the concrete mixture. It helps to gain compressive strength of concrete. But production of cement emits carbon dioxide which is the main environmental cause to replace the cement with other environmental friendly product. But researchers are finding it hard to replace it with other supplementary cementitious materials. So, now it is being tried to replace the cement partially not fully, but in huge amounts so that other waste materials, recycled products or environmental friendly products can be added to the mix proportioning of concrete.

2.3 Fine aggregate and Coarse aggregate

The particle shape and grading of fine aggregates are the important factors for the production of high performance concrete (HPC). Fine aggregates with rounded particle shape and smooth texture requires less water demand. Volume of fine aggregates should be kept minimum to increase workability and compaction. The fineness modulus of fine aggregates less than 2.5 should not be used, as it is difficult to compact.

In HPC, course aggregate may also affect the concrete strength. Smaller size of aggregates known to produce higher strength of concrete. However for optimizing modulus of elasticity, creep and drying shrinkage, higher size of aggregates are preferred. Usually the maximum size of coarse aggregates may be kept at a minimum size of 10mm or 12mm.

2.4 Silica fume

Silica fume is the by-product of industry producing silicon and ferrosilicon alloy. Silica fume has very high surface area of the order of 15,000 m^2/kg to 30,000 m^2/kg which is measured by the method of nitrogen adsorption method. The size of silica fume is very less compared to the size of cement particles. The size is almost 100 times less than that of cement particle. The percentage content of silica in silica fume is also very high compared to that present in Portland cement. It is about 85-97% in silica fume compared to 21.9% in the Portland cement. Due to the presence of high percentages of silica in silica fume and extreme surface area it is said to be very effective pozzolanic material as compared to any other SCM. The use of silica fume enables the production of very high strength concrete and it is very useful in attaining high early age concrete strength. So, while producing high performance concrete silica fume must be added.

2.5 Superplasticizer

Superplasticizers are very useful in concrete to gain high strength and better durability properties. It allows the production of concrete with low water-cement ratio. It allows the reduction of water content more than 30%. It has many advantages like it increases workability as well as durability. It also increases slump which allows easy placement of concrete. It has also little bit disadvantages like it leads to the addition of cost, increases the air entrainment in concrete, etc. There are different types of superplasticizers. Some of these are Sulphonated Melamine –Formaldehyde Condensates (SME), Sulphonated Naphthalene Formaldehyde Condensates (SNF), Modified Lingosulphates (MLS), Polycarboxylate superplasticizer-Carboxylated Acrylic-Ester Co-polymers(CAEC), etc.

3. LITERATURE REVIEW

S. S. Awanti et. al. [1], In this paper different concrete mixtures were prepared with High Volume Fly Ash Concrete with replacement of cement varying from 50% to 65%. The water/binder ratios taken were 0.30 and 0.35. Then compressive strength values were obtained at different ages. In this case near about 180 concrete cubes were made for determining the compressive strength property. The water to binder ratio is obtained to be very effective. More the w/b ratio, lesser will be the strength. Identical trend is observed with the case of Fly ash to binder ratio i.e. with higher content of fly ash/binder (FA/b or FA/cm) ratio, lower will be the compressive strength of concrete specimens. But with the increase in time it was observed that compressive strength gradually increases.

Mochamad Solikin et. al. [2] , In this paper three different factors were analyzed by preparing the different mixes to produce high strength concrete. Analyzation of different factors were the type of effective fly ash, kind of mixing water and whether basalt fibre should be used or not, etc. There were two types of fly ash used in this research such as raw fly ash and ultra fine fly ash. The kind of water that were used in the mix are also two types, these were lime water and tap water. The utilization of basalt fibre was also studied. Sometimes it was added to the mixture sometimes not. The different mixes prepared were ultra fine fly ash without the basalt fibre but with tap water, ultra fine fly ash with basalt fibre and lime water, raw fly ash with basalt fibre and tap water, raw fly ash without basalt fibre but with lime water. Then the compressive strength of these mixes in concrete was tested in concrete cylinder with 100 mm diameter and height 200mm considering the curing ages at 28 days and 56 days. After it was found that the mix proportion with the combination of high volume ultra fine fly ash and the use of lime water without the use of basalt fibre has highest compressive strength than the other combinations that were taken. Also it was observed that the optimum mix proportion almost gains the compressive strength of normal cement concrete in 28 days.

A.A. Momin et. al. [3] , In this paper locally available fine aggregates and coarse aggregates with ordinary portland cement and superplasticizer were used to produce concrete of strengths 60 MPa, 80 MPa and 100 MPa. To produce high strength or high performance concrete chemical admixtures must be added to the mixture. Silica fume must also be added to the mixture so as to gain strength similar to that of 70 MPa. Silica fume above 20% is avoided, so, Alccofine 1203 with silica fume was added to the mix so as to gain strength equals to 100 MPa. Due to lower water to binder ratio a special method of mix design was used to produce high performance concrete.

Experimental investigation conducted by P. Saravanakumar et. al. [4] studied the use of natural aggregates at different percentages. Fly ash was also used in place of cement at different percentages. Fly ash was replaced in the percentages such as 40%, 50%, 60% whereas recycled aggregates were replaced in the percentages such as 25%, 50% and 100%. Due to the replacement of natural aggregates with coarse aggregates the compressive strengths at first got reduced but with the increase in number of days it showed less reduction in strengths. Similarly with the use of fly ash in place of cement strengths at first got reduced but after sometimes the strengths was almost same as that of natural concrete. Due to the use of all these waste product huge money can be saved that is the cost can be saved upto 40%. Here different combinations can be adopted for different concrete construction work. That is for pavement work a large recycled aggregates can be used.

According to the article by Saraswati et. al. [5] the query regarding suitability of the existing IS codes on fly ash concrete was assessed. Above 35% of fly ash is not considered in the IS codes but the quantity of fly ash is not limited according to IS codes in concrete. Moreover regarding the mixing method of high volume fly ash concrete IS codes does not give any guideline. However mixing method has influence on the performance of HVFAC and other types of concrete mixes. From the point of view of economy, HVFAC should be characterized for 56-day strength. But, the mix should have required strength for construction purpose after the minimum period required for curing, that is, 14 days. HVFAC should be cured in two stages. Initial curing is dry curing for which no specification is available in any IS code. However, specification of IS 456 on wet curing is adequate.

4. RESULTS AND DISCUSSION OF PREVIOUS WORK

Under this topic some tables and graphs will be discussed which will give some idea regarding previous researches of mix proportioning of high volume fly ash concrete (HVFAC). Particularly we will discuss the paper "Mix Design Curves for High Volume Fly Ash Concrete" by S.S. Awanti and Aravindakumar B. Harwalkar.

Table -1: Mix proportions of concrete mixes with w/cm = 0.35

Mix designation/Ingredients	P.35	50F.35	55F.35	60F.35	65F.35
Water in kg/m³	154	154	154	154	154
Cement in kg/m³	440	220	198	176	155
Fly ash in kg/m³	0	220	242	264	285
Fine aggregate in kg/m³	871	807	800	794	787
Coarse aggregate in kg/m³	1059	1059	1059	1059	1059
Superplasticizer in liter/m³	9.9	1.76	1.76	1.76	1.76

Table -2: Mix proportions of concrete mixes with w/cm = 0.30

Mix designation/Ingredients	P.30	50F.30	55F.30	60F.30	65F.30
Water in kg/m³	132	132	132	132	132
Cement in kg/m³	440	220	198	176	155
Fly ash in kg/m³	0	220	242	264	285
Fine aggregate in kg/m³	937.6	871.0	864.80	858.2	851.8
Coarse aggregate in kg/m³	1059	1059	1059	1059	1059
Superplasticizer in liter/m³	15.4	3.52	3.52	3.52	3.52

In Table -1 and Table -2 two mix proportions of concrete mixes are taken with w/cm ratio 0.30 and 0.35 respectively with replacement of cement from 30% to 65%.

Table -3: Compressive strengths of different concrete mixes:

Mix designation	Cube compressive strength of concrete in MPa at the age of			Ratio of 7 day compressive strength to 28 day strength	Age factor (Ratio of 90 day compressive strength to 28 day compressive strength)
	7 days	28 days	90 days		
P.35	42.44	56.1	60.39	0.76	1.08
50F.35	27.25	42.44	51.81	0.64	1.22
55F.35	25.65	40.62	48.03	0.63	1.18
60F.35	21.65	35.17	42.36	0.62	1.20
65F.35	15.11	24.42	28.56	0.62	1.17
P.30	47.31	62.28	66.20	0.76	1.06
50F.30	30.59	52.1	62.93	0.59	1.21
55F.30	29.07	47.31	56.03	0.61	1.18
60F.30	25.07	40.84	46.43	0.61	1.14
65F.30	19.77	27.69	32.34	0.71	1.17

In this table the results of mix proportions that are taken from Table -1 and Table -2 can be observed clearly. From this table it can be said that with the increase in time the compressive strength gradually increases but with the increase in fly ash to binder ratio (fly ash/ cement) the compressive strength gradually decreases. The water to binder ratio also plays an important role in compressive strength. From this table the results are that with water to binder ratio 0.30 the compressive strengths are higher than with water to binder ratio 0.35.

5. CONCLUSIONS

[1] A concrete mix that is prepared with lower water to binder ratio has higher contribution of fly ash than the mixes that are prepared with higher water to binder ratio. The water to binder ratio should not be more than 0.4 in case of HVFAC.

[2] While producing HVFAC in plants mechanised mixers should be preferred having weight batcher instead of hand mixing.

[3] In case of HVFAC mix with low w/b ratio there is a potential risk of plastic shrinkage cracks if not cured early. So, after placing of concrete curing should be processed as early as possible.

[4] Fly ash content and water to binder ratio greatly affects the fly ash reaction that is the paste which has high volume fly ash, the fly ash reaction is lower whereas the concrete mix which has low volume fly ash, the reaction will be higher. High Volume Fly Ash Concrete has lower early strength and the strength gradually increases with time.

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