Mechanical properties of High Strength Concrete using fly ash

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***Abstract*— Recently, a number of researches have involved improving the concrete technology requirements through advanced research. These studies involved high strength concrete HSC, were highly dependent on the quality of ingredient–materials. HSC production potentially involves several trial mixes and uses high quantities of fine materials thus making it very costly and time consuming. The objectives of this study were to reduce the production cost, time required and to improve HSC properties by providing control mixes and using fly ash as partial cement replacement. This was done by experimentally investigating the HSC production using 10%, 20% and 30% replacement of cement by fly ash and selecting the optimum replacement content. All concrete mixes were homogeneous in fresh concrete state, did not show any sign of segregation and maintains slump between 80-110mm. Fly ash addition further improved the workability. At the age 90 days, all concrete mixes achieved the cube compressive strength between 80 to 120MPa. Tensile and flexural strength were increased using fly ash using fly ash. Higher strength concrete showed low ductility because the ultimate strain was found less than 0.35%, there was In general 20% fly ash content was found the optimum.**

***Keywords*— production, fly ash, optimum, workability, compressive strength and flexural strength**

I. Introduction

Concrete, is a compound material consisting of aggregates enclosed in a matrix of cement paste. The strength of concrete depends upon the strength of these components, their properties, and the bond strength between the paste and aggregate surface [1]. Many researchers have successfully produced concrete of more than 100 MPa compressive strength using natural aggregates and by enhancing the strength of the cement paste. This was done by varying the type and dosage of admixtures, and through controlling the water-cement ratio [2,3,9]. Furthermore, the development and advances in concrete technology also depends on the availability of different types of mineral and chemical admixtures.

Fly ash is a mineral admixture that is mainly a by-product of the coal –fired power plants. It is classified as pozzolanic material according to ASTM C 618 [5]. Usually, the use of fly ash as partial replacement of cement has many beneficial effects on the fresh and hardened properties, and the cost of HSC. From theoretical considerations and practical experience the authors determined that, the quantity of fly ash replacement is between 15%-30% depending on some factors. It sustainably improves the properties of HSC mixtures such as workability, ultimate strength and tensile strength reported by [7.8]. Many researches have been conducted by using fly ash in HSC since long time ago. Among them, 40% replacement of cement by fly ash resulted in an increase in strength of concrete of 23% and 38% at 28 days and 56 days respectively [9,10]. Another report showed that 40% replacement cement by fly ash with w/c ratio 0.4 has resulted in characteristic strength of 45 MPa at 28 days [11]. Generally, the benefits of incorporating fly ash in HSC have been demonstrated through extensive research and countless highway and bridge construction projects. These benefits depend on the type of fly ash, proportion used, mixing procedure and field conditions [12,13].

The main focus of this study was to produce HSC using10%, 20% and 30% replacement cement by fly ash as a mineral admixture and to determine the optimum replacement. For this purposes a series of experimental mix designs was carried out using local materials. The mix designs should 28 days strength in the range of 80- 110 MPa with slump of 80-115mm as good workability.

II. Experimental WORK

A. Materials used and mix proportions

Ordinary Portland Cement (OPC) and Sika Viscocrete 34-30, a generation superplasticizer, were used in all the experimental investigations. The mineral admixture used was Fly ash from a local source, which was supplied by Mahjung, Panven ,Perak, Malaysia . River sand has a well gradation and finesse module F.M = 2.2 was used as a fine aggregate. A well

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gradation of crushed granite, which has a little effect on the concrete strength, with specific gravity of 2.68 and size range of 9 to 20 mm, was used as a coarse aggregate. The proportion between two types of aggregate CA/FA ranges from 1.28 to 1.32, potable water ranged from (0.275% to 0.318%) was used.

Mix proportion of production HSC was selected using basic criteria. These involves quality of materials, improvement of paste cement as well as the aggregate, enhancing the bond between aggregate surface and cement paste and lastly denser packing between the both components. Many trial mixes have been done so to achieve the goals mentioned previously. Finally, five mixes labeled M1, M2, M3, M4 and M5 in table 1 were considered as HSC mixes. To enhance their durability properties and reduce the cost, 10%, 20% and 30% replacement cement by fly ash was studied in this paper. Furthermore, 20% replacement cement had been selected as the best replacement due to their 28 days strength which was considered for this investigation.

TABLE I
PROPORTION MATERIAL OF MIXES

Mix	Cement (Kg/m^3)	C. A (Kg/m^3)	F. A (Kg/m^3)	W/C ratio	S.P %
M_1	450	1030	780	0.318	2.75
M_2	475	1015	765	0.300	1.50
M_3	475	1015	765	0.288	2.00
M_4	500	1000	750	0.276	1.25
M_5	550	975	740	0.275	0.80

B- Mixing method

A tilting drum mixer with a tilt angle of X0 was considered for mixing. The mixer was a semi vertically mounted cylindrical pan fabricated to rotate about a semi horizontal axis with paddles arranged to rotate eccentrically to the pan axis. Mixing and casting concrete were at room temperature of 26 ± 2oC. During the production half amount of fine and coarse aggregate with both the cementitious materials were first placed and mixed for 15 second, and then placed with the remaining fine and coarse aggregates. Finally w/c calculated and superplasticizer were mixed together with all component materials for 5 minutes till it became fully homogenous.

A. Samples Preparation

Fresh concrete properties were tested according to ASTM C 172. The sample size specimen made for each mix was 100 mm cubes for compressive strength test. All the compressive strength cubes were cured in the water tank in accordance with ASTM C0192 and testing was done on the 3rd,7th, 28th, 56th and 90th day, according to ASTM C 39 [6]. Furthermore, samples were loaded in a compressive testing machine under control load at pace rate of 3kN/s until the specimen collapsed. In addition, 100 x 200 mm cylinder was considered for split tensile strength according to ASMT C496; load was curried at a constant rate of 0.94 KN/s splitting tensile stress up to failure. Finally, flexural tensile strength was conducted using 100x100x500 mm beam specimen for point loading according to ASTM C78, beam was loaded at a pace rate of 0.3KN/s until failure. Also stress- strain relationship was investigated by using Electrical resistance gage on the cubes. A summary describing the tests used in samples preparation is shown in Table 2.

III. Results and Discussion

The experimental investigation reported in this section focuses on the production of HSC with fly ash, its optimum quantity replacement and the conducted tests. These investigated properties include fresh concrete properties, compressive strength, split and flexural tensile strength, modulus of elasticity and stress-strain relationship. The experiments have been done for five concrete mixes with 20% replacement fly ash which was selected as the optimum replacement. The selection criteria will be discussed in the remainder part of the paper.

A. Workability of Fresh Concrete

Due to high workability requirement, the highly effective chemical admixture Sika Viscorete 34-30 ranged from 2.7% to 0.8% was used. All the mixes have lower w/c ratio ranged of 3.18% to 2.75%. Figure 1 shows the slump test results which has been done. It is observed that the target of slump which is ranged between 80 and 110 mm has been achieved for each mix produced. This was significantly improved using FA as shown in the Fig. 1. Also there was no aggregate segregation in the mixtures during production.

TABLE 2
DESCRIPTION OF STANDARD TESTS

	Fresh concrete	Mechanical properties		
Test	slump	Compressive strength	Tensile strength	Flexural strength
Standard	ASTM C 172	ASTM C39	ASTM C496	ASTM C78
sample	0.021m^3	150x150 x150mm	150x150x 300mm	100Dim x500mm
unit	mm	N/mm^2	N/mm^2	N/mm^2
Age (days)	5 min	3,7,28&90	28&90	28&90

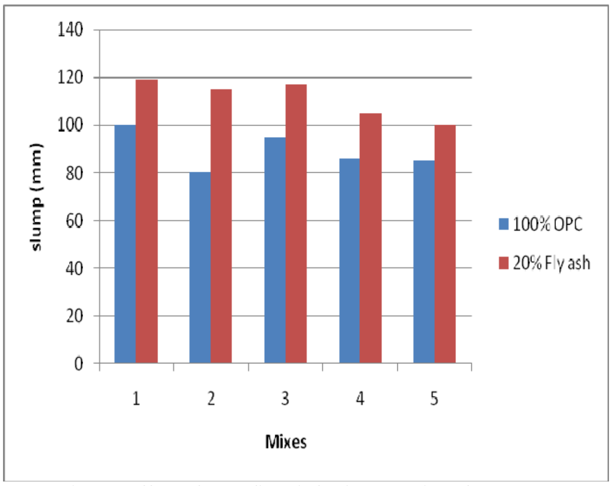


Fig. 1 Effect of 20% fly ash fresh properties of concrete.

B. Strength of Concrete

All strength test results were calculated as an average for three specimens. The obtained strength test results from control mixes with 100% cement were ranged from 85 MPa to 120 MPa at 90 days. The results were affected mainly by quality of aggregate, curing and production factors. Furthermore, the influence of the type of materials on the compressive strength of HSC was higher than the normal strength concrete.

To determine the optimum fly ash replacement ratio, HSC was produced using 10%, 20% and 30% replacement ratios as reported in Fig. 2. The highest 28 days strength for each mix has been achieved with 20% replacement of cement by fly ash. Therefore it was considered as the best replacement ratio for this investigation according to this strength. The strength results from 20% replacement are shown in Fig.3 . The results show that the early strength of HSC decreases whereas the strength increases in the long term. This is due to the effect of the fly ash on the hydration of cement.

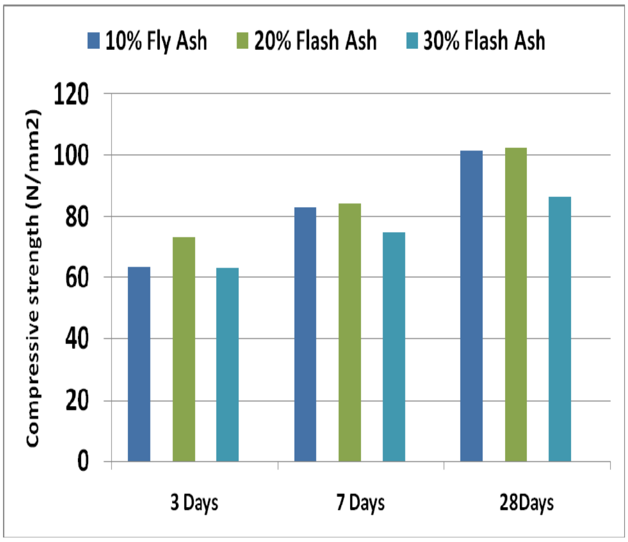
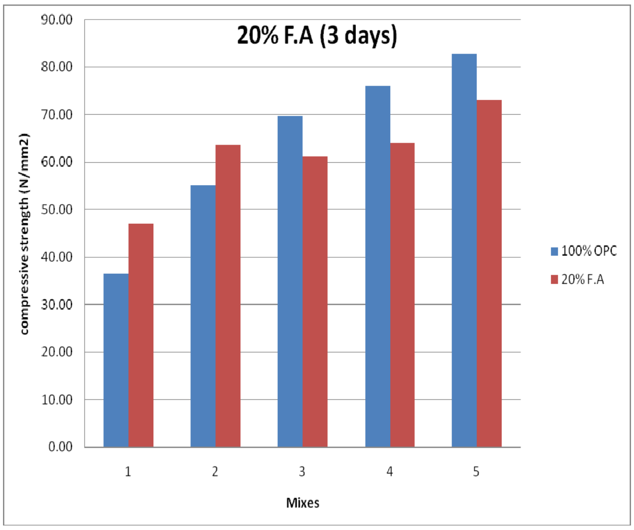


Fig. 2 Strength of 10%, 20% and 30% fly ash HSC



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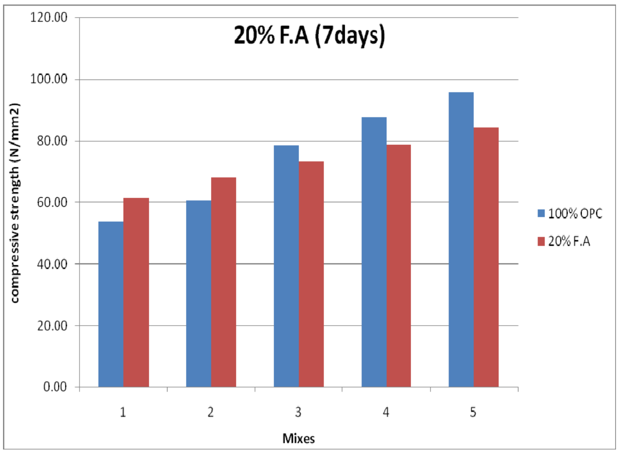

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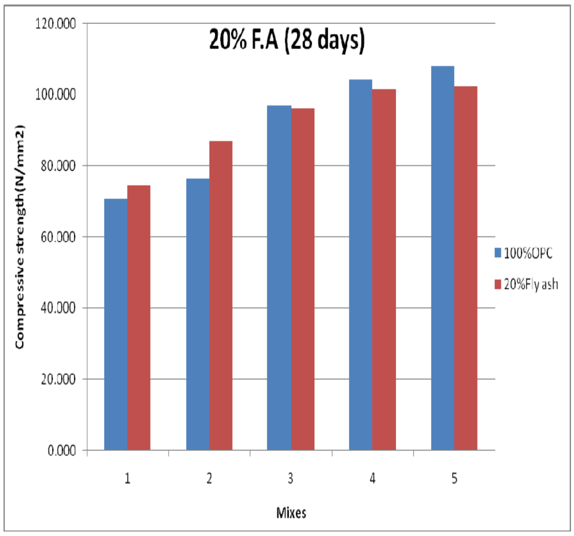

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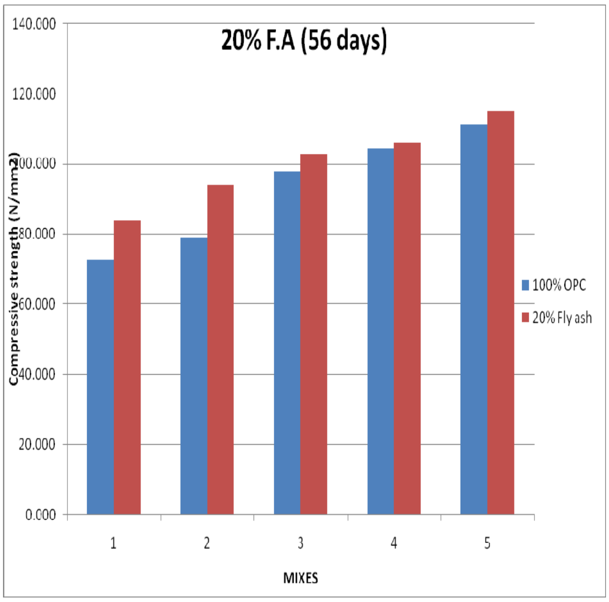

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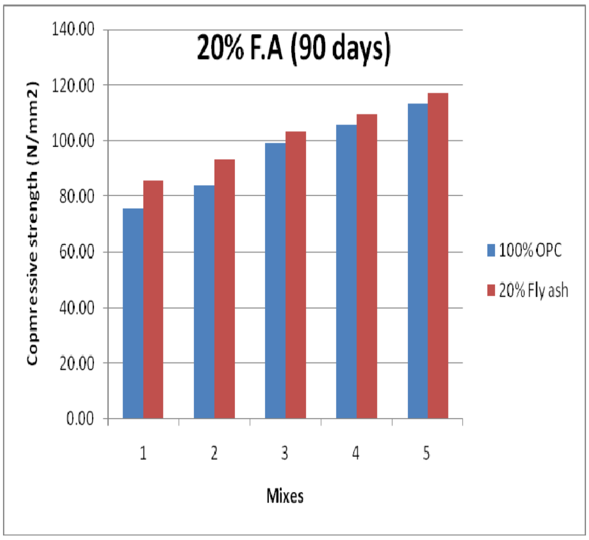
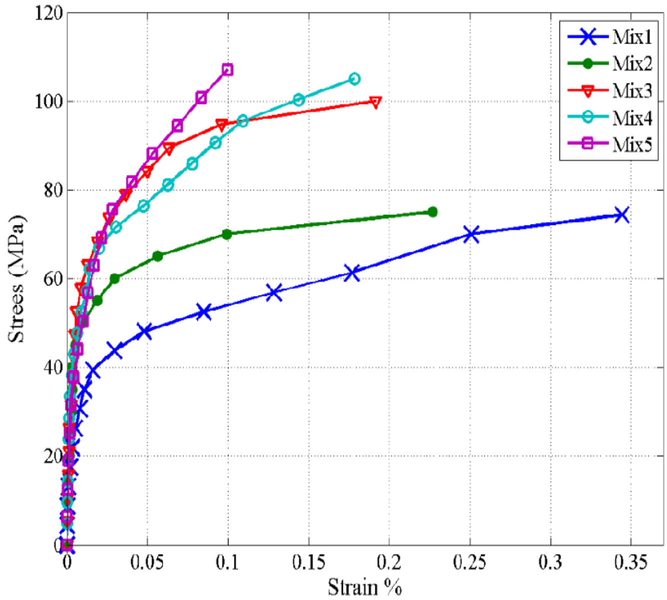
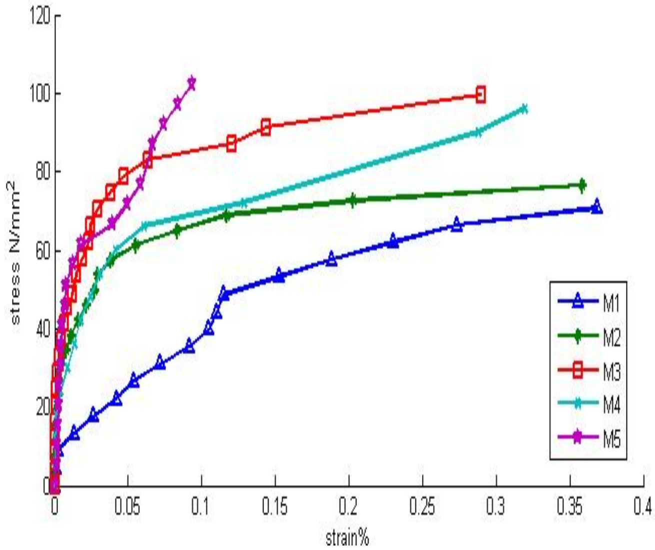


(e)

Fig. 3 Feffect of 20% fly ash on the strength of Concrete (a) after 3 days, (b) after 7 days, (c) after 28 days, (d) after 56 days and (e) after 90 days



(a)



(b)

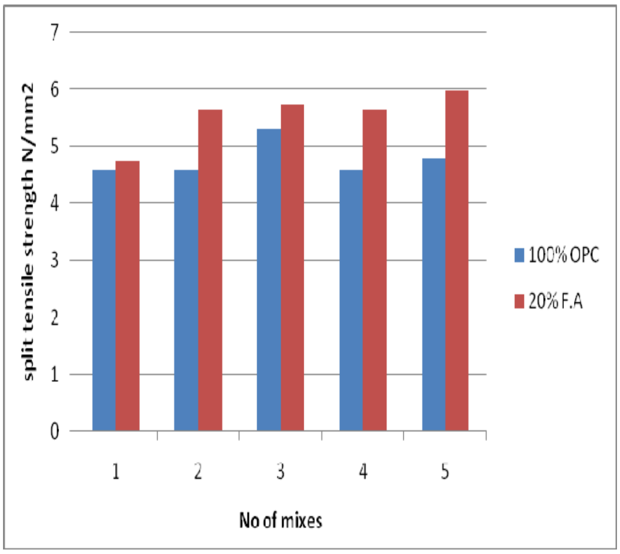
Fig. 4 stress- strain relationships for (a) 100% OPC and (b) 20% fly ash.

C. Stress- Strain Relationship

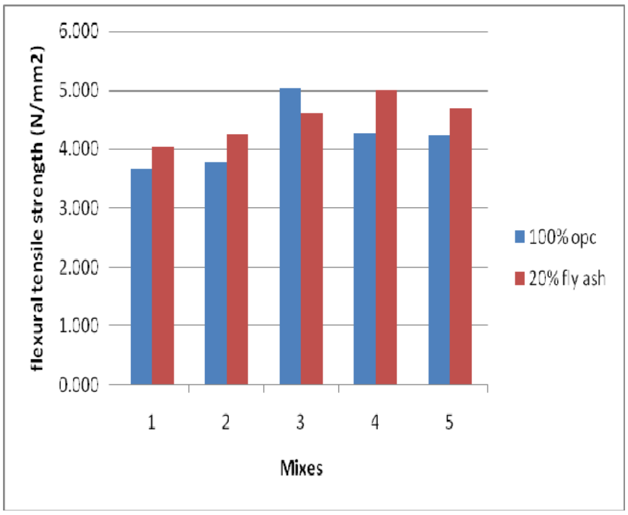
Fig 4 shows all stress-strain relationship curves for five mixes as previously mentioned. These relationships were performed using electrical resistance strain control gauge with plain cube concrete using compressive strength test machine for control mixes (Fig 4 (a)) and 20% replacement fly ash (Figure 4 (b)). It was observed from all the tests that, the strain in HSC clearly decreases with an increase in its stress, whereas the brittleness of HSC higher than the normal strength. This investigation also showed that the effect of 20% replacement cement by fly ash on the stress- strain relationship was very little or neglected as shown in Fig 4.

D. Tensile Strength

Tensile strength is a major factor affecting concrete's susceptibility to cracking, thus playing a vital role in its durability. There are three clear methods of measuring the tensile strength of concrete, either directly by tension measurements or indirectly by splitting tensile or flexure (modulus of rupture) measurements. Splitting and flexural tensile strengths were measured through the indirectly test. There was no or little effect on the tensile strength due to the increase in cement, dosage of superplasticizer and w/c ratios quantity on the mixes. Additionally, the results showed that the splitting (Fig 5 (a)) and flexural (Fig 5(b)) tensile strength increases with 20% replacement.



(a)



(b)

Fig 5 Effect of 20% fly ash replacement on: (a) the split tensile strength and (b) the flexural tensile strength of HSC.

E. *Modulus of Elasticity*

The effect of 20% replacement fly ash on the modulus of elasticity E of the five control concrete mixes was investigated at the age of 28 days. This was calculated in the strength tests as shown in figure 6. Actually, 100 mm cubes specimens were tested. All these specimens were subjected to a stress ranged from 72 MPa to 120 MPa. The modulus of elasticity was calculated according to ACI 318-95. The following equation was used to determine the elastic modulus:

$$EC= 4.7\ (f_{cu})\ ^{\wedge 0.5}$$

Where f_{cu} is the compressive strength

To estimate the equivalent cylinder streUTP will issue an undertaking for issuance of payment because of 13-3-2013 is too close for making it. Therefore, it is my kind request to you to accept the undertaking to be issued by UTP.ngth, a factor of 0.8 has been used. It was found that, the increase in strength, increases the modulus of elasticity in both concretes mixes. It was worth noting that 100% OPC and 20% replacement had similar values of elasticity as shown in Fig 6.

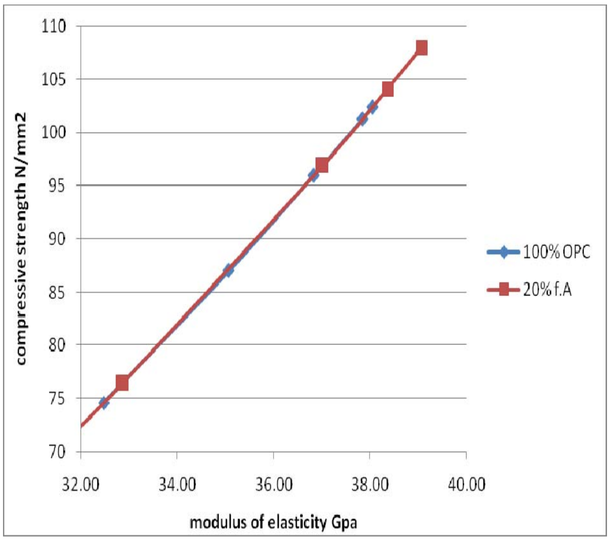


Fig 6 strength- modulus of elasticity relationship

IV. *CONCLUSION*

In this study, experimental investigation on HSC samples with total cementitious materials of 450-550 kg/m, with 1.2 to 1.32 coarse to fine aggregate ratio, 2.75% to 0.8% SikaViscorete 34-30 and various w/c percentages was carried out. In addition, 10%, 20% and 30% replacement cement by fly ash were made to improve its properties and to select the optimum reported replacement ratio. The results showed that, the effect of these constituent materials by their proportions were very significant in the HSC properties. Therefore, more precision during HSC production is needed compared to conventional strength concrete. It was observed that, fresh concrete had no aggregate segregation and the workability target was achieved in range of 80 -110 mm. It was significantly increased using fly ash. The highest 90-days strength of 117 MPa was achieved without any mineral admixtures. From the results that, the 20% replacement of cement by fly was the best replacement quantity. The compressive strength, tensile and flexural strength were remarkably improved using fly ash. The brittleness in HSC was higher than the normal concrete due to the fact that the strain significantly decreases with the increase in strength of concrete. Furthermore, there was no or little effect of 20% replacement cement by fly ash on the stress-strain relationships and modulus of elasticity.

V. References

[1] Kodur, et.al., “Structural behaviour of high strength cosncrete columns exposed to fire”, NRCC-41736, pp. 217-232, Sept. 1998.

[2] Rashid ,A. “consideration in producing high strength concrete”, IEB ,June,15,2008.

[3] Caladarone, A,M., “ High- Strength concrete”, Book , Taylor &francisGruo , London and New york, 2008.

[4] P.S. Song ,S. Hwang,. “Mechanical properties of high-strength steel fiber-reinforced concrete”,. Construction and Building Materials 18 (2004) 669–673

[5] ASTM C 618, "Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete." Annual Book of ASTM Standards Volume 4.02, ASTM International

[6] ACI Committee 211, 1993, ‘Guide for Selecting Proportions for High Strength Concrete with Portland Cement and Fly ash’, ACI 211, 4R-93, ACI Materials Journal, Vol.90, No. 3, pp. 272-283.

[7] Mehta,P.K.,and R.W.Burrows, 2001, “Building Durable Structures in the 21st Century.” Concrete International 23(3), pp. 57-63.

[8] Vengata G. K.B., 2009, ‘High volume fly ash concrete for pavements’, M.E. Dissertation, Department of Civil Engineering, Anna University, Chennai, India.

[9] Adams, T. H., 1988, “Marketing of fly ash concrete”, MSU seminar: Fly ash applications to concrete (January), 1.10, 5.10, East Lansing: Michigan State University.

[10] Naik, T. R. and Ramme B.W. 1989, ‘High Strength Concrete containing large quantity of fly ash’, ACI Material Journal, Vol.86, No.2, pp.111-116.

[11] Raju, N. K., Ipe, T. V. and Srinath, N., 1994, ‘mix Proportioning and strength characteristics of portland cement and pulverized fly ash concrete’, ICI Bulletin No. 49, pp.27-32.

[12] American Coal Ash Association, 1995, ‘Fly Ash Facts for Highway Engineers’, Federal Highway Administration, Report No. FHWA-SA-94-081, Washington, DC, December.

[13] Vanita Aggarwal, S.M.Gupta, S.N.Sachdeva, “concrete durability through high volume fly ash concrete (hvfc) a literature review”, International Journal of Engineering Science and Technology Vol. 2(9), 2010, 4473-4477