

## Performance of Fly Ash and High Volume Fly Ash Concrete in Pavement Design

Yash Shrivastava and Ketan Bajaj <sup>+</sup>

UG Student, University of Petroleum and Energy Studies, Dehradun

**Abstract.** Generally, concrete used in the field suffers from lack of durability and homogeneity. Since cement is the only binding material in concrete and due to recent hike in its price, researchers have been looking for apt substitutes. *Fly-Ash* has been discovered as a suitable supplement. Fly-Ash being a *pozzolan* reduces the cost of construction and is used for making green concrete, so its adoption enables more sustainability in the concrete industry. This paper emphasis on the performance of Fly Ash (FA) in the soil stabilization with replacement it with different soil for 10 to 60%. Besides this it presents the fresh and hardened properties such as compressive and flexural strength of High Volume Fly Ash Concrete (HVFAC) through prism and cubes, with 35%, 50% and 70% of cement replacement with fly ash. The results showed that up to 50% replacement of cement can be used for construction with in addition reduces 12% overall cost.

**Keywords:** HVFAC, FA, soil stabilization, CBR.

### 1. Introduction

The use of concrete has recently gained popularity as a resource-efficient, durable and cost effective. High Volume Fly Ash constitutes about 50% fly ash, a lower water content, low cement content and a low water-cement ratio (W:C) (about 0.4-0.45%). A concrete mix with fly ash can provide environmental and economical benefits. Fly Ash concrete enhances the workability, compressive strength, flexural strength and also increases its pumpability, durability and concrete finishing. It also reduces corrosion, alkali silica reaction, sulphate reaction shrinkage as it decreases its permeability and bleeding in concrete.

T.C. Hansen and S.E. Hedegaard [1] reported in the paper “Modified rule of constant water content for constant consistency of fresh fly ash concrete mixes” (1989) that there exists an upper limit to sum of fly ash and Portland cement, beyond which it is not possible to compact to maximum density. The principle of constant free water content for constant consistency also applies to fly-ash concrete and addition of less than 10% of concrete may destabilize the concrete. Studies carry out at Canada Center for Mineral and Energy Technology (CANMET) and University of Calgary [2] on “Fly-ash concrete” (1990) have proposed that structural concrete with 28 days strength around 60MPa and of adequate durability can be produced by the Canadian fly ash replacing up-to 60% cement by weight and incorporating high range water reducing and air entraining admixtures in concrete. Prusinski, Fouad and Donovan [3] in the paper “Properties of fly ash concrete” (1993) that the total mass of cementitious material and the optimum proportion of fly ash selected depend upon the class and the quality of fly ash, the type, quality and alkali content of Portland cement, the presence of chemical admixtures, placement condition and the parameters of strength required and also curing and the weather condition. A. Camoes [4] in his paper “Durability of High Volume Fly ash concrete” (2004) concluded that the replacement of 60% of fly ash with concrete increases the strength of concrete by 45-55 Mpa in 28 days and enhance the durability and workability of concrete by providing high carbon content and also the properties of fly ash concrete drastically affected if proper curing was not assured. Structural Engineering Research Institute [5] in the report “Demonstration of utilizing high volume fly ash

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<sup>+</sup> Corresponding author. Tel: +91-7500690903;  
E-mail address: 16ketan1990@gmail.com

based concrete for structural applications” (2005) reported that HVFAC exhibited higher strength at later ages and the flexural strength is higher for HVFAC whereas the bond strength for embedded rebar is nearly the same for both the concretes but it shows very low chloride permeability and low water absorption and reduced water permeability and have lower carbonation depth however better abrasion resistance as compared to that of OPC based concrete which increases the age of the concrete. T.P. Singh [6] in the paper “Field performance of high volume fly ash concrete- The Indian Experience” (2007) articulated that compared to conventional concrete, HVFAC has lower early compressive strength but very good later age strength which continues to increase over several months and has also performed better in terms of its elastic modulus, flexural, tensile and abrasion strengths.

The disposal of fly ash is a serious environmental problem. In India, 110 million of fly ash is produced and 2-30 percent is used and rest occupies vast tracks of valuable land as a pond. The fly ash used in concrete industry by partly replacement it with cement and also in embankment for filling the material. With the above view, the fresh and hardened of M30, M50 and M70 grade concrete with 35 percent, 50 percent and 70 percent cement replacement with fly ash have been investigated and also the geotechnical properties of fly ash has been tested with different replacement with soil and compaction results have been tested. This paper presents the effect of fly ash replacement on compressive strength, tensile strength and flexural strength of concrete along with the slump and other fresh and hardened properties. A comparative cost analysis with different replacement of fly ash has presented.

## 2. Experimental Investigations

### 2.1. Materials

Ordinary Portland cement of grade-43 is used and sand of zone-III is used as per IS-383-1970 and 20 and 10 mm coarse aggregate is used with the following properties shown in table 1, 2 & 3

Table 1: Properties of material used

PROPERTY	FINE AGGREGATE	COARSE AGGREGATE
Impact value	3.	9.76
Crushing value	-	28.95
Bulk density	1.948 g/cm <sup>3</sup>	1.635 g/cm <sup>3</sup>
Specific gravity	2.62	2.60

Table 2: Chemical Composition of FA [7]

Type	Fly Ash (present study %)	ACI requirement for class C type fly ash	I.S. specification (I.S. 3812)
SiO <sub>2</sub>	53.36	45.9	35.0
Al <sub>2</sub> O <sub>3</sub>	26.49	24.2	-
Fe <sub>2</sub> O <sub>3</sub>	10.86	4.7	-
CaO	2.42	3.7	-

Table 3: engineering and geotechnical properties of fly ash used [8]

Properties	Value
Liquid limit	23.9%
Plastic limit	13.14%
Plastic index	10.76%
Specific gravity	3.26
Optimum Moisture Content	31.2%
Maximum Dry Density	1.2 g/cc
Cohesion	Negligible
Angle of Internal Friction	35°
Permeability	1.3 × 10 <sup>-4</sup> cm/sec
Optimum Moisture Content	31%

Maximum Dry Density	1.22 /cc
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### 3. Methodologies Adopted

In this investigation, the engineering properties like compaction of sand, sand + fly ash (SF) @ (10, 20, 30, 40 & 50) and sand + fly ash + soil (SFS) @ (1:1:1, 1:1.5:0.5) had been tested and results are compared. In addition to that compressive strength of cubes was also determined at an interval of 7, 28 & 56 days with the replacement of cement @ (20%, 35%, and 50%). Besides this flexural strength of 600 × 150 × 100 prism of M20, M50 and M70 Grade with above replacement of cement had tested. Further the fresh and hardened properties like slump, temperature, modulus of elasticity, modulus of rigidity is also determined.

#### 3.1. Mixing and sampling

One control mixture M<sub>1</sub> (without fly ash) was designed as per standard specification IS 10262:1982 for the mix design of M20, M50 and M70 with target mean strength of 26.25 MPa, 56.36 MPa and 78.69 MPa. The other three concrete mix were designed with 20%, 35%, 50% and 70% replacement of cement with fly ash is made of M20, M50 and M70 grade of concrete. The compressive strength was determined by 150 × 150 × 150 mm mould and flexural strength by 600 × 150 × 100 mm prism. The detail of the cubes are given in the following table no. 4

Table. 4: Details of concrete cubes

M20			M50			M70		
Mix Identification	Concrete Proportion	Mix	Mix Identification	Concrete Proportion	Mix	Mix Identification	Concrete Proportion	Mix
M21	M20 concrete with 100 % cement + 0% fly ash		M51	M50 concrete with 100 % cement + 0% fly ash		M71	M70 concrete with 100 % cement + 0% fly ash	
M22	M20 concrete with 65% cement + 35% fly ash		M52	M50 concrete with 65% cement + 35% fly ash		M72	M70 concrete with 65% cement + 35% fly ash	
M23	M20 concrete with 50% cement + 50% fly ash		M53	M50 concrete with 50% cement + 50% fly ash		M73	M70 concrete with 50% cement + 50% fly ash	
M24	M20 concrete with 70% cement + 30% fly ash		M54	M50 concrete with 70% cement + 30% fly ash		M74	M70 concrete with 70% cement + 30% fly ash	

### 4. Results and Discussion

#### 4.1. Fly ash and soil properties

It was observed that, the MDD goes on increases with the increase in fly ash percentage and OMC goes on increases. As the percentage of fly ash increase, plastic index of the material decreases, the plastic nature of soil decreases and flow index also decreases which means shear strength of the soil increase with increase in fly ash content as shown in fig. 1. The particle size distribution chart is drawn among all the samples which are shown in fig. 2.

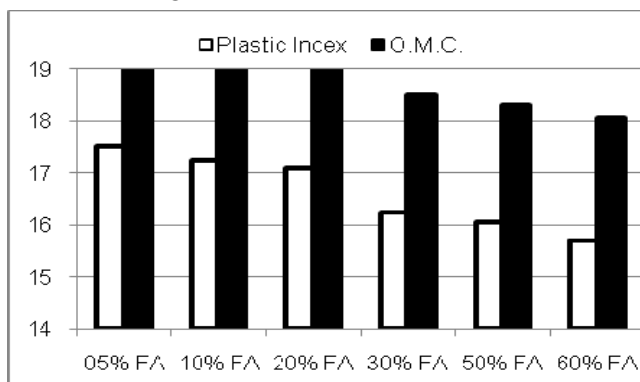


Fig. 1: Plastic Index and OMC

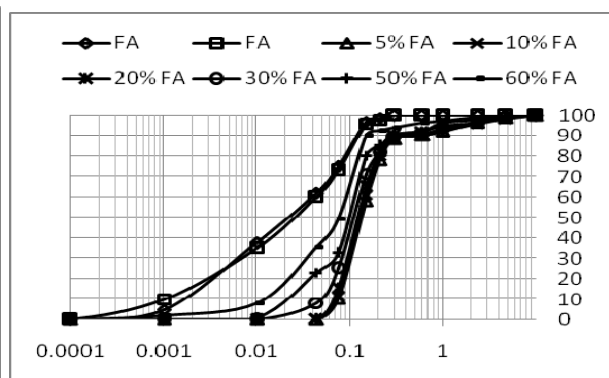


Fig. 2 : Particle size distribution curve

## 4.2. Fresh and hardened properties of HVFAC

Bleeding of the concrete was determined after 1 hr and it seems that with the increase in fly ash bleeding in the concrete goes on decreasing shown in fig. 3. The measured slump of fly ash at the constant w/c goes on increasing with the increase as shown in fig. 4.

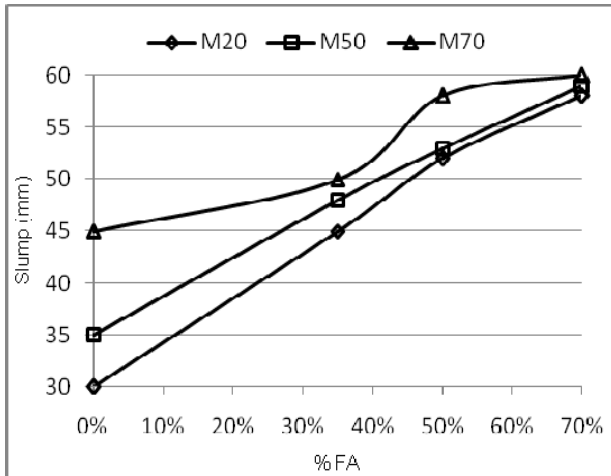


Fig. 3: showing variation in Slump

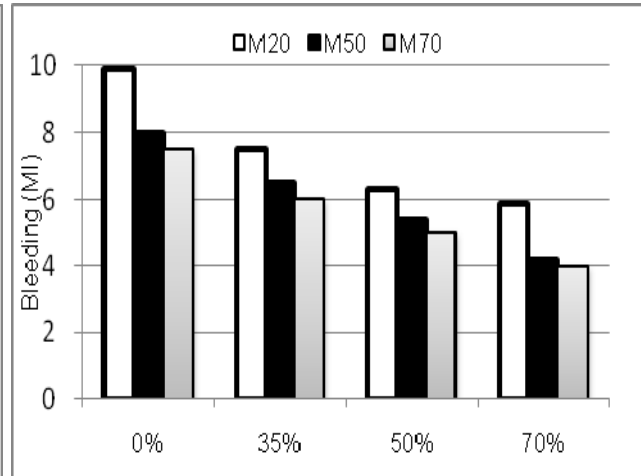


Fig. 4: showing bleeding in concrete

The compressive strength of the concrete cubes [9] had been tested at the interval of 7, 28 and 56 days. It is seen that the strength goes on increasing with the increase in fly ash but after the replacement of 50% the strength goes on decreasing with further increase. The flexural strength of concrete is tested at the interval of 7 and 28 days and it is seen that flexural strength goes on decreasing with the increase in fly ash content as shown in the table 5. With the increase in temperature compressive strength of concrete increases, due to Hot water curing [10]; compressive strength of concrete increases as 4.1%, 19.33%, 16.33%, and 29.19% shown in fig. 5

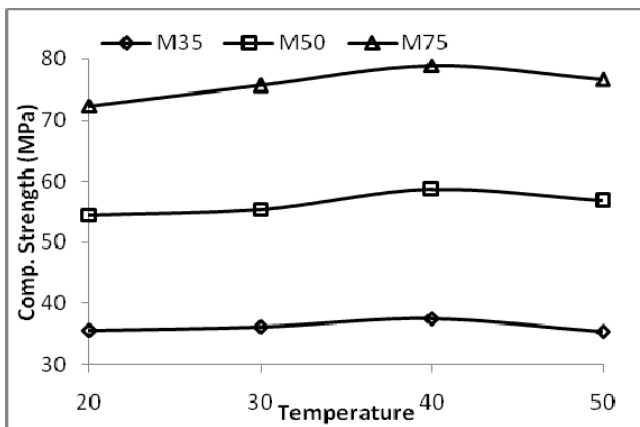


Fig. 5: Compressive Strength varying with Temperature

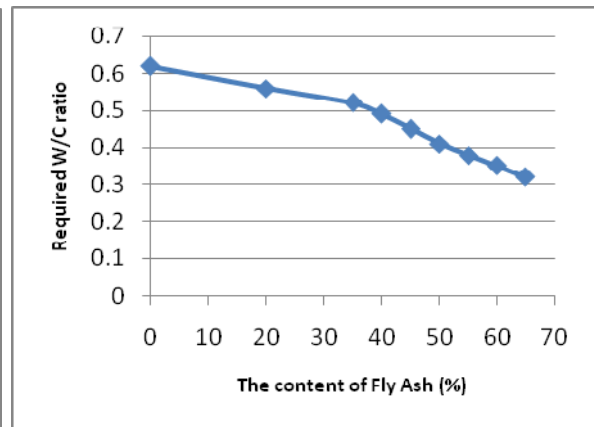


Fig. 6: W/c ratio with fly ash

Table. 5: Showing the compressive strength and flexural strength of HVFAC

Mix	M20					Mix	M50					Mix	M70				
	Comp. Strength (MPa)			Flexural Strength (MPa)			Comp. Strength (MPa)			Flexural Strength (MPa)			Comp. Strength (MPa)			Flexural Strength (MPa)	
Days	7	28	56	7	28		7	28	56	7	28		7	28	56	7	28
M21	10.4	23.3	25.3	3.3	5.1	M51	42.3	54.2	55.5	9.1	18.8	M71	55.3	72.6	74.5	18.4	24.1
M22	11.1	24.3	26.5	3.5	5.3	M52	44.2	56.2	57.2	9.5	19.1	M72	58.5	74.5	75.6	18.6	24.5
M23	23.3	26.3	29.8	3.8	6.0	M53	47.2	58.6	59.7	9.8	19.4	M73	61.5	76.8	77.5	19.1	25.9
M24	25.2	24.2	28.2	3.2	5.2	M54	46.2	54.2	55.2	9.2	19.2	M74	59.2	75.2	74.2	18.2	23.2

	3	8	5	4	2	4	3	3	8	4	0	4	5	4	6	5	5
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## 5. Conclusions

- 1) With the increase in fly ash, expansion of soil decreases and drainage characteristics becomes better and make it suitable for sub-grade and sub-base.
- 2) The workability of concrete increases whereas temperature and bleeding decreases with the increase in fly ash in concrete.
- 3) The compressive strength and flexural strength and modulus of rigidity and toughness value also increases with the increase in concrete and up to 35% replacement, the values are acceptable according to IRC:SP:62-2004. With the increase in temperature the strength of fly ash concrete increases.
- 4) There is limitation in addition of fly ash in concrete to maintain the workability of concrete.
- 5) There 10-30% reductions in cost with the addition of 50% fly ash in concrete.

## 6. References

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