



## STUDIES ON EFFECT OF MAXIMUM SIZE OF AGGREGATE IN HIGHER GRADE CONCRETE WITH HIGH VOLUME FLY ASH

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### ABSTRACT

In the present paper, an investigation is made to study the effect of maximum size of aggregate in higher grade concrete using high volume fly ash. Three different mixes of M50 grade concrete were designed using graded coarse aggregate of three maximum sizes of 10mm, 12.5mm and 20mm. And for each mix, cement was replaced with fly ash at 0%, 10%, 20%, 30%, 40% and 50% (%replacements). All the mixes were cured for 56 days and tested for compressive strength, flexural strength and splitting tensile strength. The test results obtained have suggested that the maximum size of coarse aggregate in M50 grade concrete at various replacement levels of fly ash was 12.5 mm aggregate and optimum replacement of fly ash was 30%. The percentage increase was 20% for compressive strength, 20% for splitting tensile strength and 5% for flexural strength when compared to the design strength.

**Keywords:** Maximum size of aggregate; high volume fly ash; replacement; high performance concrete

### 1. INTRODUCTION

Concrete is the choice of material in construction industry due to its inherent properties of versatility, economy, durability and ease of construction. In the present scenario of environmental protection and accomplishment of meeting huge infrastructural requirements, emerging technologies like high performance concrete, green concrete, etc., are of preference. Concrete is the most widely used material for construction since several years. It has undergone many changes from time to time for acquiring better properties. The coarse aggregate in concrete may be gravel, crushed granite, sand stone, basalt or barite, etc. The fine aggregate is generally river sand or it may be sea sand, manufactured sand or crusher dust. Water has been partially replaced with plasticizers, super plasticizers, air-entraining

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agents, viscosity modifying agents, etc. The most important material in concrete is the cement which in general sense means, any material with adhesive and cohesive properties. But this constituent has changed with time. Started with calcined gypsum, calcined lime, etc., the urgent need to reconstruct them as quickly as possible led to the development of higher grade cement.

But, very soon it was found that the use of higher grade cement gave only high early strength and failed to gain strength at later ages. The structures developed cracks within a short period of 20 to 25 years. This paved a way to the evolution of advanced concrete technologies – using the artificial pozzolans in concrete.

### *1.1 Fly ash*

Fly Ash is a by-product of coal combustion at thermal power stations. The fly ash particles are typically spherical, ranging in diameter from  $< 1\mu\text{m}$  to  $150\mu\text{m}$ . The specific surface area ranges from  $\leq 1200\text{ m}^2/\text{kg}$  to  $1300\text{ m}^2/\text{kg}$ . The specific gravity ranges from 1.90 to 2.96.

#### *1.1.1 Classification of fly ash*

Lime fly ash is divided into two categories, namely Class C fly ash and Class F fly ash. Class C fly ash contains 25% analytical CaO, generally a product of combustion of lignite and sub-bituminous coals. It is generally called as the high calcium fly ash or high lime fly ash consisting of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> in the range of 50% only. This has self cementing properties, with high fineness and light colour. Class F Fly Ash contains less than 10% analytical CaO, generally a product of combustion of anthracite and bituminous coals. It is generally called as the low calcium fly ash or low lime fly ash with the sum of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> in the range of 70%. A minimum of 50% fly ash is used with low water content and low water/cementitious ratio.

## **2. NEED FOR THE RESEARCH**

Though high strength concrete is constrained to use aggregate of 19mm or lower, its influence in high volume fly ash concrete was almost unexplored. Researches are either on the aggregate properties in high strength concrete or in high volume fly ash concrete. But a specific result indicating the influence of the maximum size of aggregate in higher grade concrete using high volume fly ash is not yet present. To fill the gaps in these aspects, an attempt is made in this investigation.

### *2.1 Objectives of the investigation*

1. To study the effect of different sizes of aggregates in concrete.
2. To study the effect of different replacements of cement with fly ash in concrete.
3. To study the effect of different sizes of aggregates in concrete using different replacements of cement with fly ash.

### *2.2 Scope of the research*

The present work is carried out to study the effect of different maximum sizes of aggregates 10 mm, 12.5 mm and 20 mm in M 50 grade of concrete by replacement of cement with 0%,

10%, 20%, 30%, 40% and 50% fly ash by conducting compressive strength, splitting tensile strength and flexural strength. Averages of 3 specimens for M50 grade concrete were cast for each mix. A total of 54 cubes, 54 cylinders and 54 prisms were cast for 18 mixes.

### *2.3 Literature review*

Rehsi [1] studied on a number of Indian fly ashes in 1973. It was found that, the water requirement of concrete was increased with inclusion of fly ash. Ghosh and Timusk [2] in their studies in 1981, showed that, in general, for the same maximum size of aggregate and for all strength levels, the shrinkage of concrete containing fly ash is lower than that for concrete not containing fly ash. Ganesh Babu and Dinakar [3] studied on concretes with 550-770 kg/m<sup>3</sup> total cementitious materials and fly ash percentages varying from 30%-40%, to achieve concretes over a wider strength range, with water-cement ratio in the range of 0.33 to 0.40, the studies resulted in self compacting concretes in the strength range of 63-93 MPa. Jain et al. [4] carried out research work at Birla Ready Mix Concrete Plant, Hyderabad for a pavement by incorporating fly ash more than 35% replacing cement. Siddique [5] studied on various concrete mixes and found that the abrasion resistance was found to increase with age for HVFA concrete mixes and found to be maximum at 60 minutes of abrasion. Lakshmanan [6] carried out experimental investigations on structural elements with HVFA concrete and found that HVFA concrete and OPC concrete mix have similar behaviour under flexural and axial loading.

## **3. EXPERIMENTAL PROGRAMME**

### *3.1 Materials*

Cement and fly ash: Ordinary Portland cement of 53 grade confirming to IS: 12269-1987 was used. Class F fly ash procured from Hyderabad Industries Limited, Hyderabad, at Kothagudem thermal power station, Andhra Pradesh was used. Potable water free from any amounts of soils, acids, alkalis, sugar, salts and organic materials confirming to IS: 456-2000 was used for mixing of the concrete and curing the test specimens. Same water was used even for evaluating the physical properties of other materials used in the concrete. The universal testing machine of 200tonne capacity was used for all specimens. All the variations of the mix proportions, workability and short term properties of the concrete are presented in Tables 1-3. Different relationships are presented in graphical form in Figures 1-6.

### *3.2 Test results and discussions*

#### *3.2.1 Workability*

The mix proportions of the different concrete mixes are presented in Table 1. The workability increased, as the maximum size of aggregate increased for all replacements of fly ash. The workability ranged from 0.76 to 0.92 for various concrete mixtures. No bleeding was observed. This may be due to the void filling action of the fine fly ash particles, which gives a high cohesion to the mix. Concrete mix proportions are presented in Table 1. Workability values for various mix cases are presented in Table 2.

### 3.2.2 Compressive strength

The compressive strength of concrete was decreased for 10mm, 12.5mm and 20mm size of aggregates for fly ash replacements from 10% to 20% and increased the strength at 30% replacement of fly ash.

### 3.2.3 Splitting tensile strength

The splitting tensile strength was found to increase from 10% to 30% replacement by fly ash and then decreased for the further replacements for the above mentioned sizes of the aggregates.

### 3.2.4 Flexural strength

The flexural strength was found to increase from 10% to 30% replacement by fly ash and then decreased for the further replacements. The values of compressive strength, flexural strength and splitting tensile strengths are presented in Table 3. The graphical representations of the test results are presented in Figures 1-6.

Table 1: Concrete mix proportions

Mix ID	Max. Size of	Fly ash	Fly ash	Cement	Coarse aggregate	Fine aggregate	Water	W/C
	Ca (mm)	(%)	(kg / m <sup>3</sup> )	(kg / m <sup>3</sup> )	(kg / m <sup>3</sup> )	(kg / m <sup>3</sup> )	(kg / m <sup>3</sup> )	Ratio
MA10F00	10	0	0.0	521.0	1250	417	188	0.360
MA10F10	10	10	52.1	468.9	1250	417	188	0.360
MA10F20	10	20	104.2	416.8	1250	417	188	0.360
MA10F30	10	30	156.3	364.7	1250	417	188	0.360
MA10F40	10	40	208.4	312.6	1250	417	188	0.360
MA10F50	10	50	260.5	260.5	1250	417	188	0.360
MA12F00	12.5	0	0.0	503.0	1270	423	183	0.363
MA12F10	12.5	10	50.3	452.7	1270	423	183	0.363
MA12F20	12.5	20	100.6	402.4	1270	423	183	0.363
MA12F30	12.5	30	150.9	352.1	1270	423	183	0.363
MA12F40	12.5	40	201.2	301.8	1270	423	183	0.363
MA12F50	12.5	50	251.5	251.5	1270	423	183	0.363
MA20F00	20	0	0.0	458.0	1322	441	169	0.370
MA20F10	20	10	45.8	412.2	1322	441	169	0.370
MA20F20	20	20	91.6	366.4	1322	441	169	0.370
MA20F30	20	30	137.4	320.6	1322	441	169	0.370
MA20F40	20	40	183.2	274.8	1322	441	169	0.370
MA20F50	20	50	229.0	229.0	1322	441	169	0.370

M = Mix, A = Aggregate size, F = Fly ash content in percentage, Ca=coarse aggregate, 00=Zero percent replacement, 10%-50% replacement

Table 2: Values of workability for the various concrete mixtures

Mix ID*	Mixtures		Slump	Compacting factor
	Maximum size of the aggregate (mm)	Replacement of Fly ash %	(mm)	
MA10F00	10	0	11	0.838
MA10F10	10	10	9	0.763
MA10F20	10	20	8	0.739
MA10F30	10	30	11	0.766
MA10F40	10	40	13	0.861
MA10F50	10	50	18	0.883
MA12F00	12.5	0	13	0.865
MA12F10	12.5	10	10	0.793
MA12F20	12.5	20	9	0.756
MA12F30	12.5	30	14	0.828
MA12F40	12.5	40	23	0.900
MA12F50	12.5	50	28	0.910
MA20F00	20	0	18	0.895
MA20F10	20	10	12	0.888
MA20F20	20	20	10	0.875
MA20F30	20	30	22	0.881
MA20F40	20	40	45	0.910
MA20F50	20	50	61	0.921

Table 3: Properties of the concrete mixtures

Mix ID*	Aggregate Size (mm)	Fly Ash Replacement (%)	Compressive Strength, at 56 days (MPa)	Splitting tensile strength @28 days (MPa)	Flexural strength @28 days (MPa)
MA10F00	10	0	57.036	4.043	5.452
MA10F10	10	10	56.524	4.201	5.647
MA10F20	10	20	53.333	4.301	5.656
MA10F30	10	30	57.003	4.514	5.773
MA10F40	10	40	42.370	3.579	4.757
MA10F50	10	50	37.333	3.211	4.160
MA12F00	12.5	0	68.140	4.084	5.680
MA12F10	12.5	10	57.238	4.273	5.760
MA12F20	12.5	20	54.814	4.373	5.867
MA12F30	12.5	30	59.903	4.895	5.945
MA12F40	12.5	40	45.036	3.854	4.907
MA12F50	12.5	50	42.518	3.381	4.367
MA20F00	20	0	59.110	4.037	5.352
MA20F10	20	10	57.146	4.109	5.431
MA20F20	20	20	54.258	4.202	5.438
MA20F30	20	30	58.459	4.368	5.503
MA20F40	20	40	44.444	3.376	4.424
MA20F50	20	50	41.110	3.095	4.056

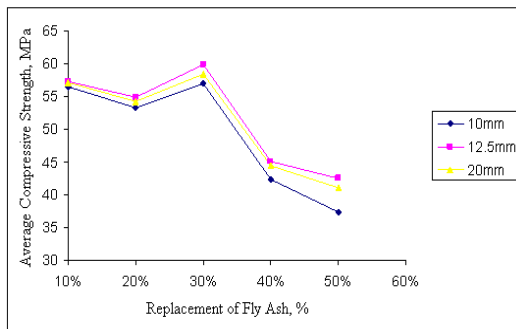


Figure 1. Relationship between average compressive strength and percentage of fly ash

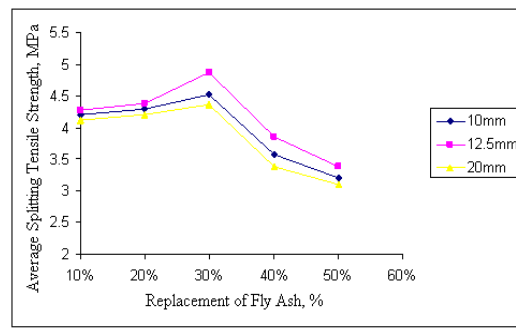


Figure 2. Relationship between average splitting tensile strength and percentage of fly ash

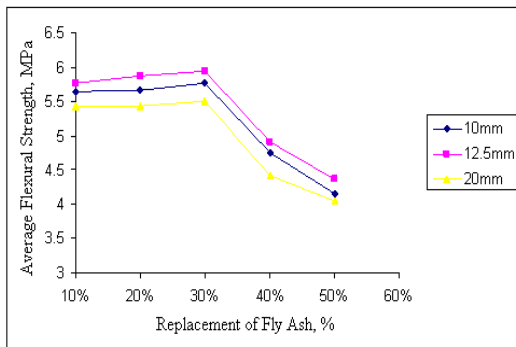


Figure 3. Relationship between average flexural strength and percentage of fly ash

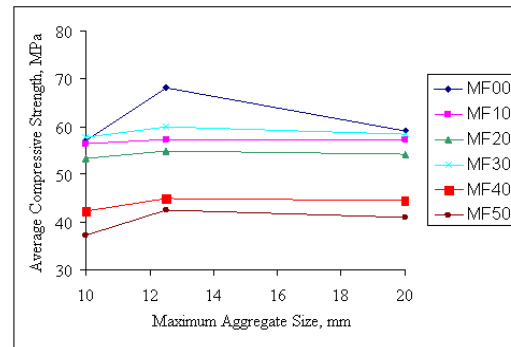


Figure 4. Relationship between average compressive strength and maximum size of aggregate

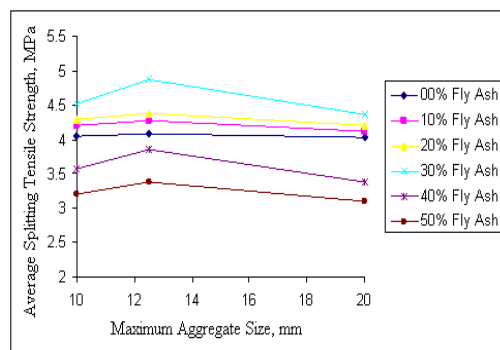


Figure 5. Relationship between average splitting tensile strength and maximum size of aggregate

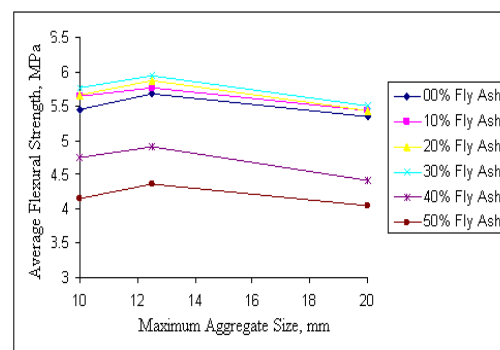


Figure 6. Relationship between average flexural strength and maximum size of aggregate

#### 4. CONCLUSION

1. Both slump and compacting factor values have shown that, the workability of concrete decreased from 0% to 20% of fly ash replacement and then increased for further replacements of 30%, 40% and 59%, irrespective of the size of the aggregate.
2. The workability of concrete increased as the size of the aggregate increased from 10mm to 20mm for all percentages of replacements of the fly ash.
3. An optimum compressive strength of 68 MPa was obtained for concrete mix containing 0% fly ash with 12.5 mm size of aggregate. Whereas, in fly ash concretes, concrete mix containing 30% fly ash replacement has shown maximum compressive strength of 60 MPa with 12.5 mm aggregate.
4. The increase was 36% when compared to the conventional concrete and 20% when compared to the mix design strength.
5. Concrete mix containing 30% replacement of cement with fly ash has shown an optimum splitting tensile strength of 4.9 MPa, using 12.5 mm size of aggregate.
6. The percentage increase was 20% when compared to the conventional concrete with 12.5 mm aggregate size.
7. The optimum flexural strength was obtained to the concrete mix containing 30% fly ash with 12.5 mm size of the aggregate in the range of 5.95 MPa. This was 5% more increased when compared to the conventional concrete containing 12.5 mm size of the aggregate.

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