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Effect of Aggregate Size and Specimen Dimensions on Mechanical Performance of Concrete

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Abstract: Concrete is a heterogeneous material. Past research has established the effect of its primary constituents namely water, cement, aggregates on the behavior at the micro level as well as the macro level. In particular, several researchers have investigated the role of aggregates on the behavior of the concrete mix, the goal being to design aggregate gradations which results in higher concrete quality. The goal of this is to study the effect of specimen size on strength in unconfined concrete.

An experimental program to determine the compressive strength of a set of unconfined concrete cylinders of varying size (100mm, 150mm, 190mm diameter) and slenderness ratio of 2 is adopted. However, while studying the effect of meso-structure on strength and size effect, care has to be taken to ensure similar levels of workability and compaction in all specimens, since otherwise no meaningful conclusions can be drawn from the test results.

Average strength of specimen is taken and It is concluded from the experimental study that with increase in size of specimen its compressive strength is observed decreased.

Keywords: compressive strength Test, size effect, meso geometry

1. INTRODUCTION

Size effect on the structural strength of concrete is deviation, due to structure size, of actual load capacity predicted from plastic limit analysis. Laboratory tests are carried out on small sized samples and the results obtained are used to predict the properties of actual structural member. Therefore, for accurate interpretation of laboratory test data, understanding of the structural size effect is very important. Size effect in concrete can be classified into two major types, energetic size effect and statistical size effect. Two types of energetic size effect can be distinguished: Type-I energetic size effect, and Type II energetic size effect. Energetic size effect is due to the release of stored energy of the structure into the fracture front. It is caused by the fact that the energy released into a propagating crack front increases roughly in proportion to the volume of the structure, while the energy dissipated in doing fracture work increases roughly in proportion to the cross-section area. Consequently, as the size of the structure increases, the stored elastic energy available to drive crack growth increases faster than the energy necessary to create new fracture surfaces (the fracture energy). As a result, crack growth occurs faster in larger structures than in smaller structures, thereby leading to smaller nominal strengths for larger structures as compared to smaller structures, and hence giving rise to a size effect.

Size effect becomes critical in the design of large structures such as dams, nuclear power plants, bridges, etc. This is because laboratory tests are performed on small scale structures and the results are extrapolated to predict the properties of large structures. Hence proper techniques for extrapolation of these results are necessary. Therefore, a proper understanding of the size effect is vital to predict the strength of large structures.

2. SYSTEM DEVELOPMENT

2.1. Materials

2.1.1 Cement

In this experimental work, UltraTech cement (PPC) was used for preparation of all concrete mixes. Cement was fresh and without any lumps. It was tested for its physical properties in accordance with Indian standard specifications. The

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physical properties obtained are given in Table 1

Table - 1: Properties of Cement

Sr.No.	Property	Test result	ISl imits
1	Fineness(sieve analysis)	3%	<10%
2	Setting time		
	Initial	113min.	>30min.
	Final	185min.	<600min.
3	Soundness	3mm	<10mm
4	Compressive strength(MPa)		
	a)7 days	26.66	Not less than22
	b)28 days	41.77	Not less than33

2.1.2 Superplasticizer

Conplast SP430 was used as superplasticizer in the concrete mixture. It is brown liquid which is instantly dispersible in water and it complies with IS: 9103: 1999 as a high range water reducer. It can be used for high water reduction up to 25% without compromising the workability and strength. It also helps to produce high quality concrete with reduced permeability. Properties of superplasticizer are obtained from manufacturer are given below in Table 2.

Table - 2: Properties of Superplasticizer

Sr. No.	Property	Results
1	Specific gravity	1.20 to 1.21 at 30^{o} C
2	Chloride content	Nil.
3	Air entrainment	Approx ... 1.5%

2.1.3 Coarse aggregate

In this work, locally available angular aggregates were used as coarse aggregates having maximum no of 20mm. Tests on aggregates were conducted for its properties as per IS 383 in the laboratory. The test results of C.A. are shown in the Table 3 and is observed within permissible limit according to IS code.

Table - 3: Physical properties of Coarse aggregate

Sr. No.	Property	Results
1	Particle shape	Angular
2	Size	20 mm max.
3	Specific gravity	2.744
4	Water absorption	1.3%

2.1.4 Fine aggregate

Locally available natural sand confirming to zone II as per sieve analysis was used as fine aggregate. Sand was sieved through 4.75mm sieve before using for concrete mixture. Various test to evaluate the physical properties of sand were conducted in the concrete lab such as specific gravity, silt content etc. according to IS 383 [10]. The test result for FA is shown in the Table 4 and is observed within permissible limit according to IS code.

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Table - 4: Physical properties of fine aggregate

Sr. No.	Property	Results
1	Particle shape	Natural
2	Size of aggregates	4.75mm
3	Specific gravity	2.70
4	Silt content	3.33%
5	Water absorption	1%

2.1.5 Water

Potable tap water without any deleterious material was used for concrete mix and curing of concrete.

2.2. Experimental Method

In this experimental work, concrete mix design for M30 grade was prepared by using IS 10262: 2019. Proportions of all the materials for each grade is given in Table 5.

Table - 5: Mix proportion for M30 grade

Sr. No.	Material	Quantity of material (NMSA 20 mm) (kg/m3)
1	Water	153
2	Cement	365
3	Fine aggregate	694.84
4	Coarse aggregate	1233.85
5	Superplasticizer	4.015

Total fifty four numbers of concrete cylinder specimens were cast of 100x200 mm, 150x300mm and 190x380 mm diameter with slenderness ratio 2 for the determination of compressive strength of concrete for design mix of grade M30. M30 concrete mix was filled in the moulds layer wise, each layer being given 30 blows using the standard tamping rod at a rate of 2 blows/s by lifting the rod 5 cm above the surface of the mix. Cast specimens were de-moulded after 24 hours and placed immediately in the curing tank and continuous moist curing was done for large specimen by covering them with jute bags for 3,7 and 28 days.

After 28 days of curing, GFRP fabric were applied to the specimen. The epoxy adhesive was prepared by mixing Lapox Lacrete epoxy resin and hardner in the ratio of 2:1. The wrapped cylinder speciemens were left at room temperature for a week for the epoxy to harden adequetly before testing.

3. RESULTS AND DISCUSSION

3.1. Compressive strength test results of cylinders

Average compressive strength for M30 grade concrete with wrapped and without wrapped GFRP was found and is shown in Table 6 and Table 7. And it shows that with increase in size of specimen, compressive strength of cylinder decreases.

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Table - 6: Mean compressive strength of different aggregate sizes cylinder

Age	10 mm NMSA			20 mm NMSA		
	Compressive Strength (MPa)			Compressive Strength (MPa)		
	100 mm	150 mm	190 mm	100 mm	150 mm	190 mm
3 Days	15.8	15.2	14.8	16.5	16	15.5
7 Days	22.8	22.0	21.5	23.5	23.0	22.5
28 Days	31.0	30.0	29.5	31.8	31.0	30.5

Table - 7: Mean compressive strength of different aggregate sizes cylinder with wrapped GFRP

Age	10 mm NMSA			20 mm NMSA		
	Compressive Strength (MPa)			Compressive Strength (MPa)		
	100 mm	150 mm	190 mm	100 mm	150 mm	190 mm
3 Days	20.5	19.8	19.2	21.5	20.8	20.2
7 Days	29.6	28.6	28	30.6	29.9	29.3
28 Days	40.3	39.0	38.4	41.3	40.3	39.7

4. CONCLUSION

The following conclusions were drawn based on the experimental results.

1. The ultimate strength of the unconfined as well as confined concrete decreases with the increase in specimen size. Hence, the existence of size effect on compressive strength of concrete columns was verified.
2. The mean compressive strength of the concrete aggregates was assessed and found to increase marginally in strength with increase in aggregates size but it could not discern clearly.
3. FRP wrapping can enhance the structural performance of concrete columns under axial loading, in terms of both capacity and ductility.
4. The ultimate strengths and strains of concrete columns increases significantly with increase in the number of FRP layer.
5. This study also concluded that for the same layer of wrapping, not much variations occur in compressive strength for cylinders of varying size.

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