Indian Journal of Natural Sciences *www.tnsroindia.org.in ©IJONS*

Vol.14 / Issue 80 / Oct / 2023 *International Bimonthly (Print) – Open Access* *ISSN: 0976 – 0997*

RESEARCH ARTICLE

Influence of Size of Coarse Aggregate on Flow Properties and Mechanical Properties of Self Compacting Concrete

S.Shrihari[1], Akella Naga Sai Baba[2]*, V.Srinivasa Reddy[3], Ambati Supraja[4] and Vithal Biradar[5]

[1]Professor, Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India.
[2]Assistant Professor of Civil Engineering, Malla Reddy Engineering College, Hyderabad, Telangana, India.
[3]Professor, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, Telangana, India.
[4]Assistant Professor, B V Raju Institute of Technology, Narsapur, Telangana, India
[5]Assistant Professor, Vidya Jyothi Institute of Technology, Hyderabad, Telangana, India

Received: 02 July 2023 Revised: 25 Aug 2023 Accepted: 23 Sep 2023

***Address for Correspondence**
Akella Naga Sai Baba
Assistant Professor of Civil Engineering,
Malla Reddy Engineering College,
Hyderabad, Telangana, India.

ABSTRACT

Size of coarse aggregate plays a crucial role in the workability and strength characteristics of concrete. Also, as usage of concrete is associated with some environmental implications, substitution of cement with endemically available pozzolanaic materials is beneficial for the environment. In this study, the combined influences of size of coarse aggregate variation and fly ash substitution have been studied. Slump test, L-Box test and V-Funnel tests were conducted to evaluate the flow properties whereas compressive and split tensile strength tests were conducted to measure the strength properties. It was noticed that the influence of size of aggregate tapered with time in case of split tensile strength attainment, whereas there was a perceptible influence on compressive strength. The role of curing period was obviously observed with progressive increase in strengths with time. Substitution of fly ash improved the workability, whereas the strength was almost the same irrespective of fly ash substitution. Thus it can be inferred that fly ash substitution and usage of 10mm aggregate can optimize the properties of self-compacting concrete.

Keywords: Self compacting concrete, fly ash, coarse aggregate, flow property, mechanical property.

INTRODUCTION

With the ever increasing population and the demand for infrastructure, there is a constant need for optimizing the strength parameters and substitution of cement with endemically available materials. Pozzolanic materials such as GGBS, Fly ash have traditionally been used as partial replacements for cement and they have shown varying degrees of success(Fantous and Yahia, 2020). However, research on the role of influence of size of aggregates in conjunction with pozzalanic material is very limited and therefore warrants investigation(Zhang, Gao and Yu, 2020). This work focuses on investigating the role of combined influence of fly ash substitution and aggregate variation in optimizing concrete and contributing towards a sustainable environment.

MATERIALS AND METHODS

Fluidity of Self compacting concrete can be measured with Slump cone. The setup typically consists of a tapered cone, broader at the bottom and is initially closed with a lid at the bottom. Into this setup, approximately six liters of freshly prepared concrete is poured. The lid is slide open and the cone is lifted up vertically swiftly, such that the concrete flows down under gravity. The time taken for reaching the 500mm diameter mark is noted down. The flowing ability of concrete is measured by simulating the actual conditions, consists of obstacles, which concrete has to face during the course of its flow. The setup typically consists of a hollow box in the shape of L. Approximately 15 liters of concrete is placed in the box and the resisting lid is swiftly opened. The heights of concrete at the heal portion (H2) and toe portion (H1) of the base of the L-Box are measured. The ratio value of (H2/H1), between 0.8 and 1 indicates a good flowing ability of concrete. V-Funnel test is used for measuring the workability of self-compacting concrete. The equipment typically consists of a V-Funnel shaped box with a trap door at the bottom. About 12 liters of concrete is poured into the box and it is emptied within a quick span of 10 seconds. Later, the time taken for the total emptying of the funnel is noted down. The lesser the time taken, more is its flow-ability. The compression strength and split tensile strength of concrete are measured using a UTM with suitable dimensions of test samples. Cement of grade 43, and varying doses of fly ash and varying sizes of aggregate were used to prepare M40 grade concrete. River sand was locally procured and used. Nan-Su method of mixing design based on packing factor is used for calculation of quantities required for one kg per cu.m.

RESULTS AND DISCUSSION

Experimental results obtained on flow properties using slump cone, L-Box and V-Funnel as well as the results attained on testing the compressive strength and tensile strength are presented and discussed in this paper. The optimal values of fly ash replacement for different sizes of aggregates under standard conditions were calculated and used for testing the flow properties and mechanical properties of concrete(Ting, Rahman and Lau, 2020). The various quantities of cement, fly ash, Fine Aggregate (FA), Coarse Aggregate (CA), Super Plasticizer (SP) and water arrived at using Nan-Su method of mix design for 10mm size of aggregate are tabulated and presented in Table.1. Similarly, the optimized quantities of cement, fly ash, FA, CA, SP, the water used and the Water Powder ratio (W/P) are given in Table.2. The quantities of Flyash required for different sizes of aggregates are presented in Table 3(a).

Similarly the flowing ability and the time taken for reaching the slump circles are given in same table. It can be noticed that when cement was substituted with Fly ash, there was an immediate increase in the flow of concrete as evidenced by the slump flow value from 610 mm to 720 mm for 10mm size coarse aggregate(Benaicha *et al.*, 2015). However, as the size of coarse aggregate was increased further onwards from 10mm, the slump flow value decreased gradually(Shrivastava and Kumar, 2016). Similarly, the results of V-funnel test and L-Box test are presented in Table. 3(b). Substitution of cement with fly ash decreased the T_o and T_{5min} flow times of concrete of V-Funnel test and the same is shown in Table. 3(b). However as the size of coarse aggregate was gradually increasedwith the addition ofFly ash, the values of T_o and T_{5min} decreased gradually(Alexandra *et al.*, 2018), indicating that the flowing ability has decreased(Chen *et al.*, 2020). L-Box results exhibited similar trend as evidenced by a little increase in (H2/H1) with addition of Fly ash and gradual decrease with increase in aggregate size(Agarwal, Masood and Malhotra, 2000). The results got from L-Box test are also given in Table.3(b).

The impact of size of aggregate used and the strength attained on curing of concrete with optimal additions of fly ash are depicted in the following figures. Fig.1., shows the impact of variation of compressive strength with variation in time and aggregate size and it can be noticed that with increase in time of curing from 3 days to 56 days, there was a steep rise in attainment of compressive strength in the initial 3 days(Nadesan and Dinakar, 2017). However, the rate of increase decreased progressively with progress in time and almost got stabilized upon reaching 56 days(Lalitha Surya Tejaswini and Venkateswara Rao, 2020). The influence of variation in size of aggregate and curing period on split tensile strength is depicted in Fig.2. Split tensile strength too followed a similar pattern as that of compressive strength except that the split tensile strengths got converged to almost the same point upon reaching 56 days(Pesaralanka and Khed, 2020). Therefore, though curing period exhibited some impact on split tensile strength, the impact of particle size was almost negligible over a long run of 56 days(Promsawat *et al.*, 2020). However, as the performance of compressive strength was good with 10mm aggregate than the other higher sizes, 10mm size aggregate can be preferred(No *et al.*, 2015).

CONCLUSIONS

1. Larger size of the aggregate needs more amount of cement compared to smaller size of the aggregates.
2. The content of fly ash increased with a corresponding decrease in aggregate size.
3. Compressive strength was found to be better with 10 mm size of aggregate.
4. The experimental results showed that 10mm size of aggregate attains more strength compared to 20mm with high volume of Fly ash.
5. Using 10 mm size of the aggregate there is reduction in the cement as compared to 20 mm.

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Table 1: Results of Nan Su method of Mix Design (10mm)

Quantities (Kg/m^3)	Pozzolana		FA	CA	SP(L/Cu.M)	Water (L/Cu.M)
	Cement	Fly ash				
	344	180	891	738	943	190.352

Similarly, the optimized quantities of cement, fly ash, FA, CA, SP, the water used and the Water Powder ratio (W/P) are given in Table.2.

Table 2: Quantities for different sizes of coarse aggregate

Size of aggregate in mm	Total powder Kg/cu.m		Fine aggregate Kg/cu.m	Coarse aggregate Kg/ cu. m	S.P Lt / cu.m	Water Lt / cu.m	W/P (Water Powder ratio)
	Cement	Fly ash					
10	315	361	891	786	9.34	194	0.34
12.5	335	241	891	786	9.34	194	0.34
16	351	225	891	786	9.34	194	0.34
20	369	207	891	786	9.34	194	0.34

Table 3 (a): Results of Slump test

Size of aggregate	**Maximum percentage of Fly ash replacement (BWP)**	**Slump flow value**	**T_{50}**
10mm	0	610mm	6 sec
10mm	46	720mm	3 sec
12.5mm	42	700mm	3 sec
16mm	39	670mm	4 sec
20mm	36	650mm	5 sec

Table 3 (b): Results of V-Funnel and L-Box tests

Aggregate size	Percentage of Fly ash replacement (BWP)	V-Funnel @T_0	V-Funnel at T_{5min}	L-Box H_2/H_1 (Blocking Ratio)
10 mm	0	5 sec	11 sec	0.81
10 mm	46	3 sec	7 sec	0.91
12.5 mm	42	3 sec	7 sec	0.89
16 mm	39	4 sec	9 sec	0.85
20 mm	36	4 sec	10 sec	0.81

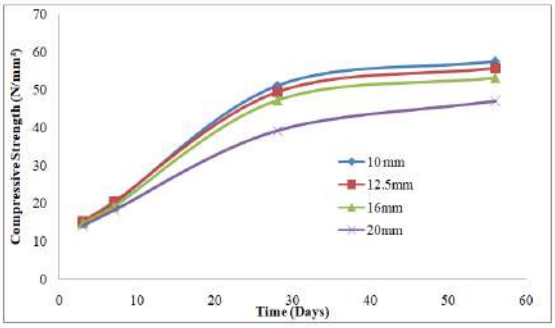

Fig. 1. Variation in compressive strength of concrete with variation in time and size of aggregate

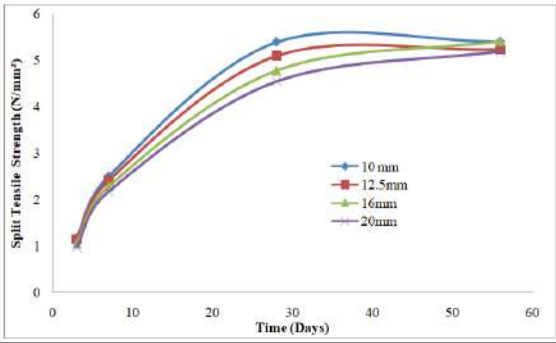

Fig. 2. Variation in split tensile strength of concrete with variation in time and size of aggregate