Effect of Recycled Aggregates on The Fresh and Hardened Properties of Fly Ash based Self-Compacting Concrete

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***Abstract*:- The present study aims to determine the mechanical properties of fly ash-based self-compacted concrete (**SCC**) and normally compacted concrete (**NCC**) prepared with natural coarse aggregates (**NCA**) and recycled concrete aggregates (**RCA**). The effect of RCA on the fresh mechanical properties such as Slump flow test, V-Funnel test, and L-Box Test and the hardened mechanical properties of SCC such as compressive strength and split tensile strength is studied. Different SCC mixes were produced with RCA substituting 0%, 25%, 50%, 75%, and 100% NCA by weight. The mix design was carried out for the M25 grade of concrete. The cube specimens were tested and the average of three samples was used as representative strength. The experimental results indicate that the strength of SCC decreases with an increase in recycled aggregate (RCA) ratios. The results are discussed with reference to the existing literature, guidelines, and codes of practice.**

Keywords: Self–compacting concrete, Fly Ash, concrete, Recycled Concrete Aggregates, filling ability, passing ability

INTRODUCTION

The human desire is increasing day by day to construct new structures and to demolish old ones. Most of these are used for land fill. as a result of the lack of dumping sites and the increased cost of transportation [1]. Construction and demolition waste (CDW) is delivered to direct landfills, posing a serious environmental risk [2]. The increase in the use of concrete in various sectors requires a huge quantity of natural aggregates, as aggregates are the key filler materials in concrete. CDW causes various environmental impacts, such as the use of landfill space, illegal deposits, and siltation of rivers and lakes, besides the mere wastage of valuable materials. Notwithstanding these negative aspects, only some countries have high recycling ratios of CDW, such as the Netherlands or Denmark, with ratios of over 90% [3]. On the other hand, there are countries such as Spain and Portugal with still low recycling ratios, at around 10% and 5%, respectively.

This discrepancy may be explained by the existence in the first countries of laws that regulate reuse and recycling, imposing target ratios and stiff fees for dumping in landfills [4]. The global aggregates consumption is approximately 20,000 billion kg per year, with a 4.7% annual growth rate predicted. Therefore, Japan and several other countries around the world have been facing shortages of natural aggregates [5] [6]. For this reason, the study of the use of this demolition waste has been reinforced by researchers around the world [7]. Recycled coarse aggregates (RCA) are primarily made up of separate natural coarse aggregate and aggregate mixed with old cement mortar [8]. However, the use of RCA may potentially reduce concrete quality as coarse RCAs are generally of poorer quality than natural coarse aggregates, with greater water absorption and lower density [9].

In 2015, the construction industry generated approximately 900 million tonnes of building and demolition waste (CDW) [5]. In general, it was reported that concrete made with RA exhibits less durability due to its high pore volume, leading to higher permeability. This will be mainly influenced by the recycled aggregate gradation and replacement ratio. Many researchers show that the use of supplementary cementitious materials (SCMs) can overcome this problem through improving the pore structure and reducing the volume of macro pores [10]. Concrete in slabs, beams, and columns, especially at congested reinforcement areas, requires a high degree of compaction which is impossible to achieve at the construction site [11]. Self-compacted concrete (SCC) is the better choice for this purpose [12]. Self-compacting concrete (SCC) is a high-performance concrete that flows under its own weight to completely fill the form work and self-consolidates without any mechanical vibration [13]. Such concrete accelerates the placement, reduces the labour requirements needed for consolidation and finishing and eliminates environmental pollution. When a large quantity of heavy reinforcement is to be placed in a reinforced concrete (RC) member, it is difficult to ensure that the formwork gets filled with concrete, which is fully compacted without voids or honeycombs. Compaction by hand or by mechanical vibrators is very difficult in this situation. The typical method of compaction and vibration causes project delays and additional costs. Underwater concreting always requires fresh concrete, which could be placed without the need for compaction; in such circumstances, vibration has been simply impossible [14].

This problem can now be solved with self-compacting concrete. This type of concrete can flow easily around the reinforcement and into all corners of the formwork. Self-compacting concrete is also known as self-consolidating concrete [15]. Self-compacting concrete is placed or poured in the same way as ordinary concrete but without vibration [16]. It is highly flowable and can pass around obstructions and fill all the nooks and corners without the risk of either mortar or other ingredients of concrete separating out. At the same time, there is no entrapped air or rock pockets [17]. This type of concrete mixture does not require any compaction and saves time, labour, and energy [18]. The surface finish produced by self-compacting concrete is exceptionally good, and patching will not be necessary. Self-compacting concrete has been successfully used in Japan, France, Denmark, the Netherlands, and the U.K., apart from India. It is gaining wide acceptance because no vibration is needed and noise pollution is eliminated. The construction process is safer and more productive. Development of the first practicable SCC by researchers (Okamura, Ozawa et al. 1989) at the University ofTokyo and the large Japanese contractors (e.g., Kajima, Maeda, Taisei, etc.) quickly took up the idea [19]. The contractors used their large in-house R&D facilities to develop their own SCC technologies. Each company developed their own mix designs [20], trained their own staff to act as technicians for testing on sites, and tailor-made their SCC mixes for large projects they tendered for. Importantly, each of the large contractors also developed their own testing devices and test methods.

Experimental program

The experimental programme was designed to study the sulphate resistance of self-compacting concrete and self-compacting sand concrete incorporating recycled concrete aggregates with different sizes obtained by crushing demolished concrete. A total of 7 different mixtures were produced and tested.

Materials

Cement

Ordinary Portland Cement 53 grade is adopted in this work. It is dark grey in colour and conforms to IS 12269-2013. The physical properties of the cement are presented in Table I.

Fly Ash

It is a material which solidifies while suspended in exhaust gases and is collected by an electrostatic precipitator. They are commonly spherical in shape and range from 0.5 m to 300 m. Class F fly ash is used for the present investigation. The properties are shown in **Table I.**

Table- 1: Physical Properties of Binder Materials

Properties	Cement	Fly-ash
Fineness	5%	21%
Specific Gravity	3.14	2.62
Consistency	35%	30%
Initial setting time	40 Min	1.30 Hr
Final setting time	8 Hr	9 Hr

Table- 2: Constituents of OPC and FA

Chemical constituents (%)	OPC	FA
Silicon dioxide (SiO_2)	20.4	50.45
Aluminum oxide (Al_2O_3)	6.20	4.5
Iron oxide (Fe_2O_3)	3.09	2.1
Calcium oxide (CaO)	63.90	20.6
Magnesium oxide (MgO)	1.50	1.7
Sodium oxide (Na_2O)	0.50	0.8
Potassium oxide (K_2O)	0.49	0.35
Loss of ignition	3.10	2.43

The natural river sand (NS) of rounded particle shape and smooth surface texture conforming to Zone-II, IS: 3812-2000 has been used. Recycled aggregates used in this work were obtained from an old concrete cube of the concrete technology lab (possibly 2 years old based on the recovered amount), with a nominal size of 10 mm. The coarse natural aggregate was obtained from a nearby stone quarry with a nominal size of 12 mm, the maximum size used in the investigation. The properties of both coarse aggregates are presented in **Table 3.**

Table 3. Properties of NCA and RCA

Properties	NCA		RCA		FA
	10 mm	20 mm	10 mm	20 mm	
Specific gravity	2.66	2.7	2.6	2.5	2.6
Water absorption (%)	1	0.9	2	1	0.84
Bulk density (kg/m^3)	1590	1560	1600	1590	1690
Fineness modulus	6.7	7.2	6.5	7.0	2.36
Impact value (%)	15	16	14	17	--
Crushing value (%)	25	26	23	25	--

TEST METHODS

The entire test programme was divided into two parts. i) Properties in their initial state; and ii) Strength investigations

Fresh State Properties

Self-compacting concrete is characterised by its flowing ability, passing ability, filling ability, and segregation resistance. For any concrete to be characterised as self-compacting, it should possess the above-mentioned characteristics. In this experiment, the following test methods as suggested by EFNARC were used: Slump flow tests for flowability, V funnel and T500 tests for viscosity, and L-box tests for passing ability are all available. The segregation resistance was observed visually during the slump flow test. Table 4 gives the recommended values by EFNARC of SCC for structural purposes for different tests.

Table 4. Typical range of values of workability

No	Method	Typical range of values (mm)	
		Min	Max
1	Slump test flow	550	850
2	T500 Slump flow	2	10
3	V-funnel Test	9	25
4	L-box test	0.8	1

Properties of Fresh Concrete

Some experiments such as slump-flow, T50, V-Funnel, L-Box J-Ring, and Orimet Test were conducted to determine the workability of SCC. Out of the seven trial mixes under test, two mixes (SCC 5 and SCC 6) comply with the required criteria for SCC. SCC 1, SCC 2, SCC 3, and SCC 4 are rejected because the resulted slump-flow value was outside the desired range of 650 mm to 800 mm.

The test mixes; SCC 5 and SCC 6 fulfil all relevant criteria and do not show a tendency to segregate and hence are declared as SCCs. The **Table 5** displays the results of different tests of workability of the SCCs.

Table 5. Fresh concrete properties of SCC with fly-ash

Mix	Slump test		V-Funnel (sec)	J-Ring Height difference (mm)	L-Box (H2/H1) ratio	Orimet (sec)	Result
	Slump Flow (mm)	T50 (Sec)					
Limit value	650-800	2-5	6-12	3-10	0.8-1	0-5	
SCC 1	400	-	-	-	-	-	Failed[1]
SCC 2	480	-	-	-	-	-	Failed[1]
SCC 3	520	-	-	-	-	-	Failed[1]
SCC 4	600	7	11	10	0.98	6	Failed[1]
SCC 5	655	5	9	8.3	0.91	5	Passed
SCC 6	700	5	7	6.5	0.89	3	Passed
SCC 7	870	4	5	5	0.85	3	Failed[2]

Failed[1] slump flow value below the standard limits (concrete does not flow)
Failed[2] slump flow value beyond the standard limits (segregation occurs, concrete over flows)

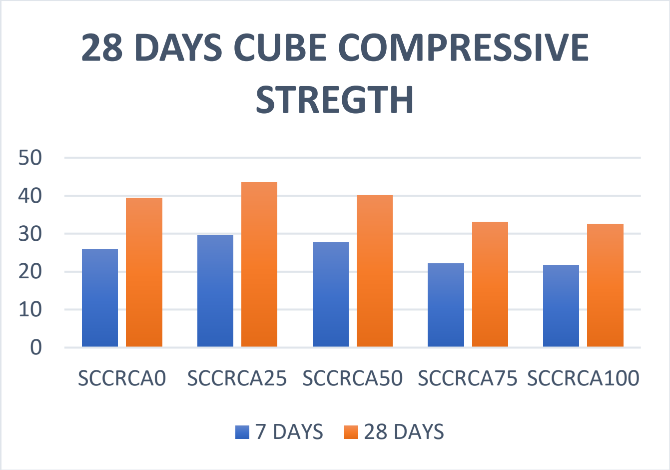
The slump-flow values of the SCC trail mix SCC 5 and SCC 6 were observed at 655 and 700 mm, respectively, which are within the limits of 650 mm to 800 mm. The slump flow time (T50) of these mixes was observed when the concrete was slumping until it reached 5 sec to start flowing. The V-funnel flow time was observed at 9 sec and 7 sec for trail mix 5 and mix 6, respectively, which lies in the range of 6-12 seconds. The test results of this investigation indicate that all SCCs mixed meet the requirements of allowable flow times. The maximum size of coarse aggregate was kept at 16 mm in order to avoid blocking effects in the L-Box. The gap between the re-bars in the L-Box was 35 mm. The L-Box ratio H2/H1 for the SCC 5 and SCC 6 was observed to be 0.91 and 0.89, respectively, which is within the limits.

Harden Concrete Properties:
The cube compressive strength of concrete after 7 days and 28 days of fly ash-based SCC with a different percentage of RCA as coarse aggregate is shown in the below chart.

Compressive Strength

Table 6. Cube Compressive Strength

Mix	7 Day, 3 cube Average Compressive strength (MPa)	28 Day, 3 cube Average Compressive strength (MPa)
SCCRCA0	26.0	39.45
SCCRCA25	29.6	43.42
SCCRCA50	27.7	40.12
SCCRCA75	22.1	33.02
SCCRCA100	21.8	32.61



CONCLUSION

The following conclusion is reached based on experiments and test results on fresh and hardened concrete: concrete drowns.

1. The workability of concrete made without SCC has been found to be increased with an increase in the RCA percentages at a fixed ratio.
2. The compacting factor of fresh concrete made without SCC has been found to increase by up to 25% and then decrease with increasing RCA percentages.
3. The 7-day cube compressive strength of concrete made with different percentages of RCA is increased up to 25% and then suddenly decreases in strength.
4. The 28-day cube compressive strength of concrete made with different percentages of RCA is also increased up to 25% and then suddenly decreases in strength as the percentage goes higher to 20%.

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