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Pro-Ecological Utilization of Crushed Concrete as an Aggregate to Improve the Compressive Strength with Steel Fibers and Styrene-Butadiene Rubber Latex

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ABSTRACT

Demolition of old structures and pro-ecological utilisation of such demolished concrete waste materials must be considered an important ecological issue that helps conserve non-renewable natural resources. Crushed concrete in the form of recycled coarse aggregate (RCA), steel fibres (SF) of 30–50 kg/m^3 and styrene-butadiene rubber (SBR) latex of 5%, 10%, and 15% by cement weight attempted to strengthen the strength in compression of polymer modified steel fiber reinforced crushed concrete (PMSFRCC). Ninety-nine cubes each of M20, M25, M30, and M40 grade were cast separately to assess the strength in compression of natural aggregate concrete (NAC), crushed concrete (CC), and PMSFRCC. According to the experimental results, PMSFRCC with SF 30 kg/m^3 and SBR Latex 5% by weight of cement improves compressive strength by 8.92% & 6.22% in mix-1, 7.63% & 5.45% in mix-2, 4.27% & 7.87% in mix-3, and 9.87% & 7.46% in mix-4 when compared to NAC at 28 and 90 days.It reflects significant improvement and validation of utilisation of CC as a potential source of an aggregate to improve compressive strength for the desired purpose.

Keywords: pro-ecological; crushed concrete; recycled coarse aggregate; compressive strength; steel fibers; SBR Latex.

INTRODUCTION

Under the influence of ecological regulators, the construction industry is increasingly using broken concrete as an input in the manufacturing of new concrete [Kumatha and Vijay, 2010], a process known as crushed concrete (CC). When Europe's urgent reconstruction needs arose after 1945, a huge task of recycling waste resources, notably building demolition materials, into new concrete construction was undertaken, with notable outcomes. Cement manufacturing, which is used to produce concrete, is one of the main sources of persistent CO_2 emissions into the atmosphere. [Behara et al., 2014]. In 2018, construction and demolition (C & D) debris generation peaked at more than 3.0 billion metric tonnes per year in 40 countries globally, and it continues to grow. The immediate beginning of RCA is concrete buildings, concrete roads, prefabricated concrete units, and other structures that are abandoned or dismantled [Padmini et al., 2009; Parekh and Modera, 2011]. With C & D of building waste materials, a new aggregate is produced and used for renewable concrete production [Hashempour et al., 2020]. Examination of the environmental impact evaluation of the forms for getting normal aggregates and the generation of their substitutes from squandering within the city mining framework was carried out [Zegardło, 2021]. Numerous researchers worked on CC with the addition of steel fibres and Styrene Butadiene Rubber Latex, as mentioned below. Hardened state properties of conventional concrete and crushed concrete are 50% and 100% replacement of crushed concrete aggregate with normal aggregate is carried out. It found that 50% replacement of crushed concrete aggregate by normal aggregate showed improved compression, indirect tensile, and flexural strength results compared to normal concrete [Harish et al., 2020]. The extent of water absorption in recycled aggregate is significantly greater [Topcu, 1995; Topcu and Sengel, 2004]. Researchers examined the lateral fatigue performance of recycled aggregate concrete reinforced with steel fibres. The dosage of recycled concrete aggregates (RCA) replacements in normal concrete aggregate (NCA) (i.e., 0%, 50%, and 100%), the presence of fibres, and stress cycles were all factors in their research. It was discovered that when the number of RCA substitutions in NCA increases, the quality of no fibre concrete decreases. Steel fibre concrete of all mixtures had a higher compressive strength than no fibrous concrete [Heeralal et al., 2009]. He conducted an experimental study to observe the effect of steel fibres on the compressive strength of recycled aggregate concrete. The water/cement ratio, recycled aggregate, fly ash, and steel fibre volume proportion of 1.5 percent m^3 of concrete were the testing parameters. Steel fibres boosted the 28-day strength properties by 10 to 30 %, according to the studies [Akinkurolere, 2010]. They researched recycled steel fibre concrete with a different percentage replacement of NCA by RCA. In the research, recyclable steel fibre fragments were used to replace NCA by 0 %, 25%, 50%, and 100% in concrete production. Research work revealed that recycled aggregate, strength in compression was dependent on concrete mix proportions. Generally, recovered aggregate‘s strength in compression was 15–25% in comparison to that of natural aggregate concrete [Zhao-xia et al., 2011]. It was discovered that by strengthening the concrete with random fibres, inherent weaknesses in high-strength concrete are avoided [Prathipati et al., 2020]. Several preliminary studies identified a mix of RCA and SF for the beam. More experimental and structural investigations are necessary. Furthermore, despite the desired ecological benefits of utilising RCA, the sustainability of such a mix with SF addition is unknown [Tam et al., 2013; Tam et al., 2014].

They discovered that reused aggregate concrete with 0.25% fibres made up of steel per cubic metre exhibited 7.27% lower strength in compression than NAC in mix-1 of M25. When compared to the NAC of mix-2 of M40 grade at 28 days, it is 11.64% lower. [Awchat and Kumthekar, 2021]. With ageing, the percentage of latex in the concrete increases, and the strength in compression decreases. Compressive strength was reduced when SBR latex was added to cement mortar due to the lessened mechanical properties of latex, which made the mortar more solid due to its hard-and-fast tolerance. The decreased remuneration was due to the plasticizer effect of rubber on the water/cement ratio. These two factors work together to maintain strength in compression for any latex percentage [Barluenga and Olivares, 2004]. They discovered that when polymer cement enhancers were added, strength in compression decreased, but compression strength at a 20 % polymer-cement ratio was higher than at a 10 %. Concrete hydrate-polymer connections were also shown to have lower strength than concrete hydrate-cement hydrate connections. The greater the amount of polymeric modifiers, the greater the capping impact, which improves strength in compression [Hwang et al., 2007]. It was discovered that incorporating 15% SBR through a 5% volume proportion of reinforcement mesh inside the polymeric ferrocement specimens improved strength in compression. Thermoplastic mortar has a higher strength in compression than unaltered mortar [Rajkumar and Vidivelli, 2010]. They experimented that the 28-day strength in compression of M20 grade of concrete was enhanced because of the polymer addition. In comparison to ordinary concrete without polymers, the strength in compression of M20 concrete improved by 15.94, 29.61, and 33.3% for 5, 7.5, and 10% polymer concentrations, respectively. Concrete grades M30, M40, M50, and M60 produce comparable results. The compression strength of M30, M40, M50, and M60 concrete categories was increased by 24.35%, 23.84 percent, 20.65%, and 16.25%, respectively, when 10% polymer was added. With the use of polymer, the rating increment in strength in compression gradually diminishes as the concrete grade advances [Bhikshma et al., 2010]. They considered the impact of

SBR rubber on cementitious materials' mechanical characteristics. With a 10% increase in the polymer/cement combination, strength in compression decreased and improved slightly for those recovered at 7 days and 28 days. At three days, it was somewhat lower for that alleviation. The strength in compression was higher the longer the healing time was [Wang et al., 2011]. They looked at the effectiveness of SBR in concrete repair. [Radhakrishna et al., 2012] found that the strength in compression estimates of SBR modified mortar cubes were slightly lower than those of cement mortar cubes. The influence of polymer adjustment on concrete's mechanical and structural characteristics was investigated. According to test data, the strength in compression of polymer modified concrete increases as the polymeric ratio increases from 5% to 15%. It aimed to reduce at an ideal rate of about 15% [Sivakumar, 2011].

OBJECTIVES OF RESEARCH

The mechanical and physical properties of NCA, RCA, sand, cement, water, SF, and SBR latex were examined in the first phase of this research. In the second phase, concrete cube samples were tested directly by a compressive strength measurement using a compression testing machine. After obtaining experimental outcomes, the comparative analytical investigation of direct compressive strength results for all mixes is carried out in the subsequent paragraphs.

MATERIALS AND METHOD

Aggregates

Locally available crushed basalt stone from a nearby quarry is utilised as a parent source of an aggregate for the preparation of four NAC mixes, according to [BIS 383, 2016]. Crushing waste material from a 40-year old residential building was used to create RCA and is introduced in Figure 1. Table 1 shows the physical and mechanical parameters of NCA and RCA.

When both 20 mm and 10 mm sieves are utilised for sieve analysis, the term "graded sieve analysis" must be used [BIS 383, 2016]. As shown in Figures 2 and 3, all five NCA and RCA trial results come within expected limits of aggregate passing in the range of 90–100% for 20 mm, 25–55% for 10 mm, and 0–10% for 4.75 mm. The result of a graded aggregate's sieve analysis confirms its appropriateness as NCA and RCA for the manufacturing of NAC and RAC [BIS 383, 2016]. In all four mixtures, 20 mm and 10 mm (NCA and RCA) were deemed 60% by weight and 40% by weight, respectively.

Sand

It planned to make four grades of concrete with Godavari river sand from Nanded, Maharashtra, India (latitude 19.1114 North, longitude 77.2945 East). Table 2 shows the actual parameters of river sand, and Figure 4 shows a sieve test of river sand.

Figure 4 depicts the overall percentage clearance requirements for five river sand test results: 90–100% for 4.75 mm, 75–100% for 2.36 mm, 55–90% for 1.18 mm, 35–59% for 600 μm, 8–30% for 300 μm, and 0–10% for 150 μm.The grading Zone-II validating parameters were confirmed by sieve analysis of river sand using five mix proportions in the institute's concrete technology laboratory [BIS 383, 2016].

Fig. 1.A. Natural coarse aggregate

Figure 1.B. Recycled coarse aggregate

Table 1. Physical and mechanical attributes of 20 mm NCA and RCA

Observations	NCA	RCA
Physical characteristics		
Specific gravity	2.96	2.64
Fineness modulus	7.40	5.15
Water absorption	0.515%	2.715%
Flakiness index	15.48%	12.64%
Elongation index	19.78%	33.12%
Soundness by $MgSO_4$	0.4924%	-0.5776%
Soundness by Na_2SO_4	0.4036%	-0.4246%
Mechanical characteristics		
Crushing value	12.55%	25.42%
Impact value	11.36%	26.07%
Abrasion value	9.77%	27.16%

Table 2. Material properties of Godavari river sand

Characteristics	Testing outcome
Specific gravity	2.61
Fineness modulus	3.95
Water absorption	7.51%
Silt content	0.6%

Cement

Ordinary Portland Cement [OPC] grade 43 was utilised in the present work, which was approved by [BIS 8112, 1989] and presented in Table 3.

Water

The institute's Environmental Engineering laboratory determined that the tap water used for casting cement concrete samples was safe [BIS 456, 2000]. Table 4 lists the results based on laboratory tests.

Stainless steel fibers

Steel fibres are made from 0.60 mm stainless steel wire with a length of 30 mm. Steel fibre with a density of 7850 kg/m^3, a tensile strength of 1695.94 N/mm^2, and a ratio of 50 (length to diameter ratio) was used in this study and was approved by [A820–01, 2013].

Styrene-butadiene rubber latex

SBR latex is a chalky white solution with a viscosity of 300–500 cP and a relative density of 1.05. It mainly consists of 25–45% rubber; the remaining seems to be mostly water, with a small intake of protein and resin materials.

Chemical admixture

Commercially available chemical admixture known as Auramix 350 (Type F & G) supplied by Fosroc Chemicals, India is applied in M40 grade (mix-4) of NAC, CC, and PMSFRCC at

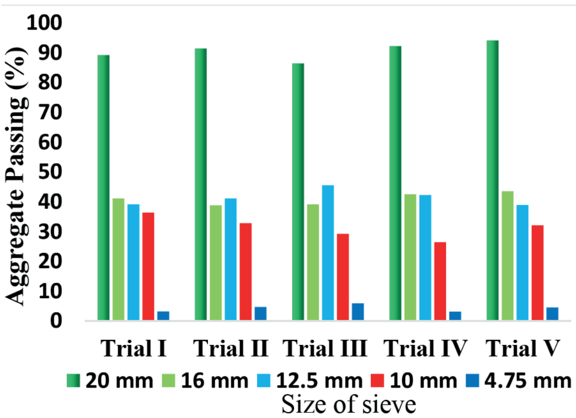

Figure 2. NCA grading sieve analysis

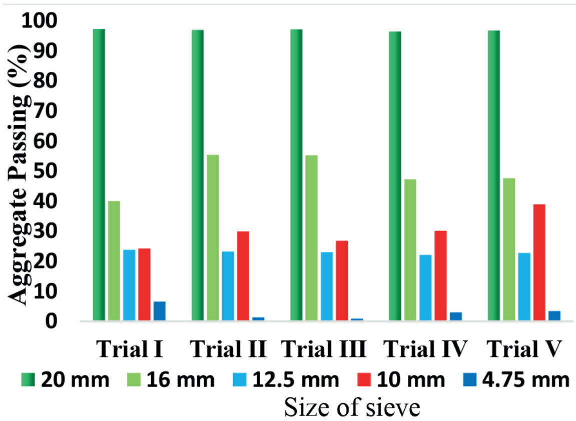

Figure 3. RCA grading sieve analysi

Table 3. Chemical parameters of OPC 43 cement

Chemicals available	Results	Permissible limit [BIS 8112,1989]
$\frac{CaO - 0.7SiO_2}{(2.8SiO_2 + 1.2Al_2O_3 + 6.5\ Fe_2O_3)}$	0.90	0.66 to 1.02
Al_2O_3 / Fe_2O_3 (% by mass)	1.35	0.66 min.
Insoluble residue (% by mass)	1.69	3.0 max.
Magnesia (% by mass)	3.03	6.0 max.
Sulphuric anhydride (% by mass)	1.68	3.0 max.
Total loss on ignition (% by mass)	1.75	5.0 max.
Total chloride (% by mass)	0.015	0.10 max.

Table 4. Water's chemical properties

Component	Outcomes	Allowable Maximum Constraints [BIS 456, 2000]
pH	6.43	6.5–8.5*
Chlorides	40	2000
Sulphates	129	400
Fluorides	0.04	1.5
Organic solids	43	200
Inorganic solids	120	3000

All parameters in mg/l, except pH.

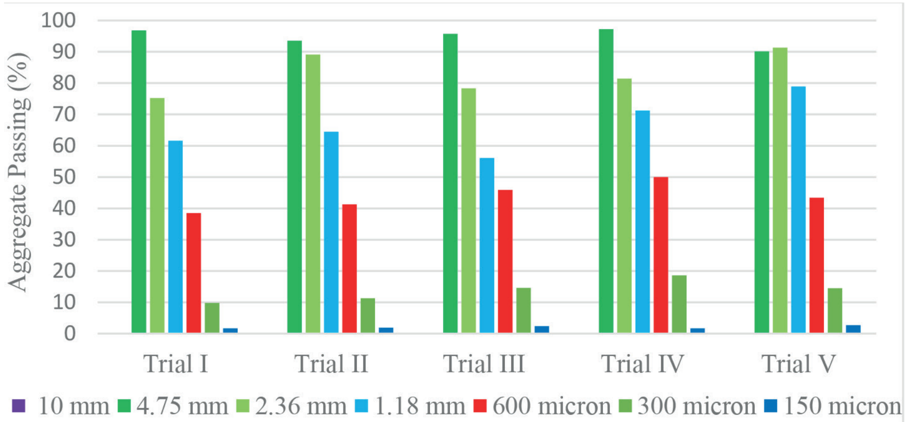

Figure 4. Sieve analysis of Godavari river sand

0.5 kg per cubic meter. It is a high-performance super plasticizing admixture (retarding type) based on a polycarboxylic ether polymer consisting of long chains. It is used for low-grade and high-grade concrete. Its electrostatic distributional consequences reduce the amount of water required in flowable concrete by a significant amount, hence it is instantly dispersible in water. It exposed the larger surface area to the hydration process by effectively dispersing the concrete mix's cement particles. It has high water reduction and long workability retention in the concrete mix. The conditions stated by [BIS 9103, 1999] are achieved by this chemical combination.

METHODOLOGY

Mix proportions

No mix design recommendations for including RCA in concrete have been established by the Indian Standard Code; the standard method of mix design is available as per [BIS 456, 2000], [BIS 10262, 2009] & [SP 23, 1982] referred to and used for the production of all samples of four NAC mixes. Later, NCA was replaced by 100% with RCA to obtain CC mixes of the same earlier designed four grades [Bairagi et al., 1993]. Final weight mix proportions were established in stated work through laboratory trials, and they were verified as M20 [1: 2.04: 3.97: 0.54] as mix-1, M25 [1: 1.89: 3.51: 0.50] as mix-2, M30 [1: 1.72: 3.22: 0.47] as mix-3, and M40 [1: 1.58: 2.94: 0.38] grade as mix-4. Table 5 shows the weight mix proportions of four different mixtures.

Sample prepration

Materials were accurately weighed and added in a tilting blender machine to get the uniform consistency of concrete. After being altogether blended and vibrated into the IS moulds of a cube-shaped specimen in three layers of equal depth and removed from the mould after 24 hours, taken after water curing at 7, 28, and 90 days, and at a temperature of 27 ± 2°C, it was tested. The cube specimens of size 150 mm x 150 mm x 150 mm were utilised to test strength in compression. Figures 5a and 5b show the materials used for casting cubes of CC.

Table 5. Mix compositions of mix-1,mix-2 ,mix-3 and mix-4 for NAC,CC & PMSFRCC

Mix ID	OPC (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	NCA 20 mm (kg/m^3)	NCA 10 mm (kg/m^3)	RCA 20 mm (kg/m^3)	RCA 10 mm (kg/m^3)	SF (kg/m^3)	SBR (%)
Mix – 1									
NA	345	186	704	821	548	0	0	0	0
RA	345	186	704	0	0	821	548	0	0
RAF1P1	345	186	704	0	0	821	548	30	5
RAF1P2	345	186	704	0	0	821	548	30	10
RAF1P3	345	186	704	0	0	821	548	30	15
RAF2P1	345	186	704	0	0	821	548	40	5
RAF2P2	345	186	704	0	0	821	548	40	10
RAF2P3	345	186	704	0	0	821	548	40	15
RAF3P1	345	186	704	0	0	821	548	50	5
RAF3P2	345	186	704	0	0	821	548	50	10
RAF3P3	345	186	704	0	0	821	548	50	15
Mix – 2									
NB	386	193	728	812	542	0	0	0	0
RB	386	193	728	0	0	812	542	0	0
RBF1P1	386	193	728	0	0	812	542	30	5
RBF1P2	386	193	728	0	0	812	542	30	10
RBF1P3	386	193	728	0	0	812	542	30	15
RBF2P1	386	193	728	0	0	812	542	40	5
RBF2P2	386	193	728	0	0	812	542	40	10
RBF2P3	386	193	728	0	0	812	542	40	15
RBF3P1	386	193	728	0	0	812	542	50	5
RBF3P2	386	193	728	0	0	812	542	50	10
RBF3P3	386	193	728	0	0	812	542	50	15
Mix – 3									
NC	425	200	741	821	547	0	0	0	0
RC	425	200	741	0	0	821	547	0	0
RCF1P1	425	200	741	0	0	821	547	30	5
RCF1P2	425	200	741	0	0	821	547	30	10
RCF1P3	425	200	741	0	0	821	547	30	15
RCF2P1	425	200	741	0	0	821	547	40	5
RCF2P2	425	200	741	0	0	821	547	40	10
RCF2P3	425	200	741	0	0	821	547	40	15
RCF3P1	425	200	741	0	0	821	547	50	5
RCF3P2	425	200	741	0	0	821	547	50	10
RCF3P3	425	200	741	0	0	821	547	50	15
Mix – 4									
ND	490	193	774	865	576	0	0	0	0
RD	490	193	774	0	0	865	576	0	0
RDF1P1	490	193	774	0	0	865	576	30	5
RDF1P2	490	193	774	0	0	865	576	30	10
RDF1P3	490	193	774	0	0	865	576	30	15
RDF2P1	490	193	774	0	0	865	576	40	5
RDF2P2	490	193	774	0	0	865	576	40	10
RDF2P3	490	193	774	0	0	865	576	40	15
RDF3P1	490	193	774	0	0	865	576	50	5
RDF3P2	490	193	774	0	0	865	576	50	10
RDF3P3	490	193	774	0	0	865	576	50	15

a) 

b) 

Figure 5. Steel fibers (a), SBR latex (b)

Testing of specimens

In all, 396 concrete cubes of the M20, M25, M30, and M40 grades were cast in eleven batches. Out of which the first two batches of 36 cubes were formed for NAC and CC using four w/c proportions of 0.54, 0.50, 0.47, and 0.38, and the following nine batches of 36 cubes were formed in RAC utilising SF at 30 kg/m^3, 40 kg/m^3, and 50 kg/m^3 and SBR latex at 5%, 10%, and 15% by cement weight.

RESULTS AND DISCUSSIONS

Material properties

RCA has a lower specific gravity, more water absorption, a lower fineness modulus, a lesser flakiness index, and a greater elongation index when contrasted to NCA. The results obtained for RCA are very consistent with the findings of [Harish et al., 2020]. Water absorption results from RCA validated findings [Topcu, 1995; Topcu and Sengel, 2004]. Although RAC can be used in a high-quality framework, despite its limitations, it ought not to be dismissed that CC with a low water content would be difficult to work with. Because RCA has a tendency to hold water, concrete mixtures that have water in them must be looked at very carefully when CC is used.

Furthermore, protection from mechanical action, for example, impact, abrasion, and crushing value, is fundamentally higher for RCA than for NCA. It is observed that RCA is generally more vulnerable than NCA against mechanical actions. Crush and impact resistance for concrete other than wearing surfaces should not exceed 45%, and 30% for concrete used for wearing surfaces, such as streets, runways, and asphalt, according to [BIS 2386–4,1963a].The values of crush and impacting resistance of RCA are 25.42% and 26.07%, though they are 12.55% and 11.36% for NCA. The abrasion strength of RCA is 27.16%, while it is 9.77% for NCA. The mechanical properties of RCA were estimated and found to be within the allowable limits of [BIS 2386–4, 1963a].Hence, it mirrors its materiality for use on wearable surfaces. The aggregate soundness examination, as specified in [BIS 2386–5, 1963b], is conveyed to choose the aggregate capacity to oppose excessive volume change as a result of changes in states of being. As a guide, it very well may be assumed that the normal loss of weight after 10 cycles ought not to surpass 12% and 18% when tried with sodium sulfate and magnesium sulfate. RCA converts sodium sulfate and magnesium sulfate into weight via the pores on the exterior surface, whereas NCA loses weight. Subsequently, the turn-around aftereffect of the adequacy test is seen in RCA when contrasted with NCA.

Impact of SF and SBR latex on the concrete mix's direct compressive strength

Figure 6 shows the compressive strength and hardening period of different mix-1 concrete specimens. Compressive strength is marginally higher than NA at 28 and 90 days after RA with various amounts of SF and SBR latex. RAF1P1, RAF1P2, and RAF1P3 exhibit compressive strengths that are 1.81%, 5.21%, and 6.90% lower than NA after 7 days. Compressive strength at seven days of RAF2P1, RAF2P2, and RAF2P3 is 4.78%, 7.35% & 10.25% less than NA. Similarly, RAF3P1, RAF3P2 and RAF3P3 is having 10.73%, 12.46% & 9.92% less strength than NA at 7 days. 7 days strength observed less RA made with SF and SBR latex because of insufficient air curing of polymer with the existence of SF.

For mix-1, RA possesses 34.65%, 32.36, and 17.14% lower compressive strength than NA at 7, 28, and 90 days, respectively. At 28 and 90 days, the compressive strength of RAF1P1, RAF1P2, and RAF1P3 improved by 2.61%, 5.79%, and 10.67%, and 3.51%, 4.94%, and 9.33%, respectively, relative to NA. At 28 and 90 days, RAF2P1, RAF2P2, and RAF2P3 showed an increase in compressive strength of 8.14%, 9.02%, and 15.40%, and 7.70%, 11.36%, and 13.61%, respectively, compared to NA. The concrete with 40 kg/m^3 SF and 10% SBR latex by cement weight in mix-1 improved significantly in strength. Because of the enhanced holding and interconnecting characteristics of the mortar, RCA, SF, and SBR latex, compression strength was enhanced. Strength in compression of RAF3P1, RAF3P2, and RAF3P3 increased by 10.68%, 12.25%, and 14.62% at 28 and 90 days, respectively, compared to NA.

Figure 7 indicates the interaction of compressive strength and hardening age for various concretes of mix-2. Concrete specimens made of SF and SBR latex in various quantities in RB indicate a marginal increase in compressive strength at different curing ages than NB. The compressive strength of RBF1P1, RBF1P2 and RBF1P3 is 2.05%, 4.55% and 6.21% less as compared to NB at 7 days. RBF2P1, RBF2P2, and RBF2P3 have 6.21%, 6.80%, and 9.70% less compression strength than NB after 7 days. Similarly, at 7 days, RBF3P1, RBF3P2, and RBF3P3 have 9.48%, 12.12%, and 8.53% less strength than NB, respectively. It observed that a 7-day curing period seems insufficient for complete air curing of polymer with SF. RB exhibits 37.27%, 31.09%, and 27.70% less compressive strength than NB at 7, 28, and 90 days, respectively, for mix-2. It seems that RB achieved strength with the age of concrete. RBF1P1, RBF1P2, and RBF1P3 compressive strength are slightly higher than 5.60%, 8.23%, 13.20%, and 6.06%, 8.12%, and 10.10% at 28 and 90 days, respectively, when compared to NB.

RBF2P1, RBF2P2, and RBF2P3 increased by 9.93%, 12.222%, 17.19%, and 5.91%, 13.42%, and 14.90%, respectively, at 28 and 90 days in comparison to NB. Concrete made with 40 kg/m^3 SF and SBR latex 10% by cement weight was shown to have the greatest strength improvement in mix-2. The results show that RBF3P1, RBF3P2, and RBF3P3 have slightly higher compressive strength than NB by 10.95%, 13.23%, and 15.57% at 28 and 90 days, respectively. RB‘s compressive strength with various volume portions of steel fibres and SBR latex is generally increasing as old mortar has a high absorption efficiency which is attached to RCA, and RCA‘s irregular texture improves their gripping and locking abilities as well.

Figure 8 represents the correlation of compressive strength and concrete age for various mixes of mix-3. At 7 days, the strength in compression of RCF1P1, RCF1P2, and RCF1P3 is 2.64%, 5.51%, and 6.84% lower than that of NC. At 7 days, the strength in compression of RCF2P1, RCF2P2, and RCF2P3 is 7.0%, 8.60%, and 12.5% lower than that of NC. Similarly, at 7 days, RAF3P1, RAF3P2, and RAF3P3 have 10.97%, 11.33%, and 9.36% less strength than NC. Experimental results confirmed that a 7-day curing period is insufficient for complete air curing of polymer in the presence of SF. Thus, it reflects a reduction in compressive strength. RC exhibited 43.19%, 35.99%, and 29.68% less strength in compression as compared to NC of mix-3 at 7, 28, and 90 days,

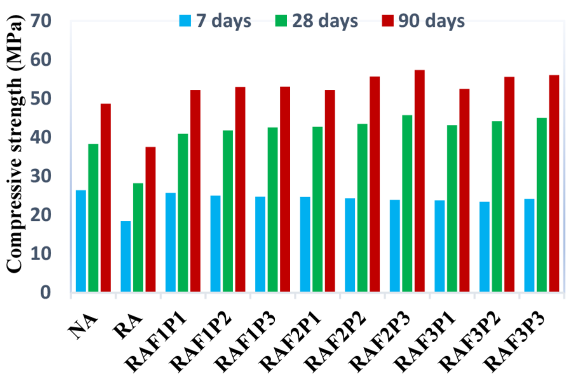

Figure 6. Results of mix-1’s comp. strength

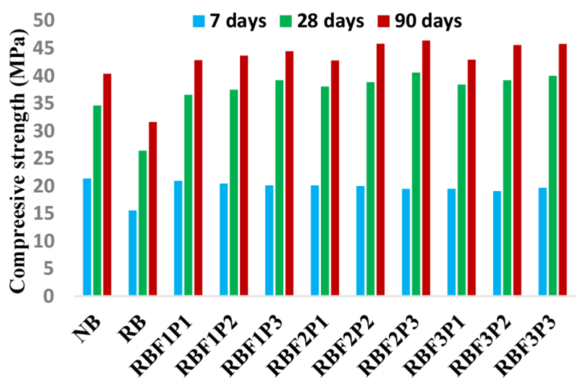

Figure 7. Results of mix-2’s comp. strength

respectively. Strength in compression was added because of further developed holding as mortar, RCA, SF, and SBR latex have interlocking properties. RCF3P1, RCF3P2, and RCF3P3 strength in compression results at 28 days were observed to be greater than RC & NC with 30 kg/m^3 SF and SBR latex accounts for 5% of the weight of cement in mix-3.indicate an increase in the strength in compression of RCF1P1, RCF1P2, and RCF1P3 as compared to NC by 0.33%, 0.29%, and 2.01%, respectively. Results showed a slight increase in strength in compression at various concrete ages for RCF2P1, RCF2P2, and RCF2P3 compared to NC. Results show that the strength in compression of the material has decreased for RCF3P1, RCF3P2, and RCF3P3 by 4.81%, 3.1%, and 2.36 percent from 28 to 90 day healing periods when compared with NC.

Figure 9 shows the strength in compression and healing period of various types of mix-4 concrete. At 7 days, the compressive quality of RDF1P1, RDF1P2, and RDF1P3 is 5.49%, 8.43%, and 9.08% less when contrasted with ND. The reduction in compressive strength of RDF2P1, RDF2P2, and RDF2P3, when determined with ND, is 8.88%, 10.22%, and 13.23% at 7 days. Thus, the strength in compression of RDF3P1, RDF3P2, and RAF3P3 at 7 days is generally lower than that of ND, with 11.28%, 14.47%, and 11.07%, respectively. This lessening in strength at 7 days demonstrates deficient air restoring of the polymer at an early age in the nearness of SF. RD shows 34.67%, 28.87%, and 25.53% when there is less strength in compression compared to ND at 7, 28, and 90 days, respectively for the mix-4. The expansion in strength is seen because of the new connection between SF and SBR latex. Results demonstrated an increase in the compression strength of RDF1P1, RDF1P2 and RDF1P3 compared with ND by 9.98%, 12.72%, 13.08% and 11.30%, 13.28%, and 14.41% at 28 and 90 days separately. Results showed an expansion in the compressive strength of RDF2P1, RDF2P2, and RDF2P3 compared to ND by 13.39%, 15.55%, and 21.57%, and 12.77%, 16.99%, and 19.85% at 28 and 90 days. The greatest strength over time was seen because of the advancement of a new connection between 40 kg/m^3 SF and SBR latex, 10% by cement weight in mix-4. The strength in compression increased as a result of the study for RDF3P1, RDF3P2, and RDF3P3 when contrasted with 14.55%, 17.79%, and 19.35% and 11.97%, 15.88%, and 17.73% at 28 and 90 days individually.

It was discovered that the concrete contains some bulk cement paste in the interfacial transition zone (ITZ), but that the cement paste in the transition zone is of poor quality. Due to internal bleeding, water will gather under the huge, elongated, flaky RCA fragments. In general, ITZ weakens the bond between the paste and the RCA. When we examine the shape and content of crystalline materials (such as calcium hydroxide and ettringite) in the interfacial transition zone, we can see that they are quite small. This explains why the resistance of ITZ in RA is lower than that of bulk cement slurry. Tam et al. (2014) [Tam et al., 2014]. Because of the high absorbency of the old mortar attached to RCA and the rough texture of RCA, the mortar, RCA latex, SF, and SBR have better holding and interlocking qualities, and the compressive strength of CC and SF has increased in the early stage. The findings of this investigation corroborate those of [Exteberria et al., 2007; Salem & Burdette, 1998]. It was also discovered that the strength gain in CC is higher at 28 days than at 90 days when compared to NAC. Similar findings were obtained for curing periods ranging

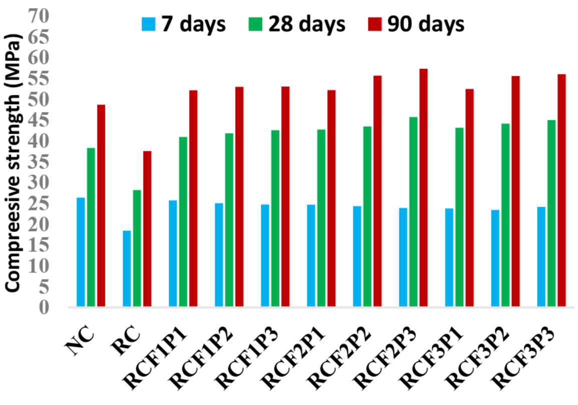

Figure 8. Results of mix-3's comp. strength

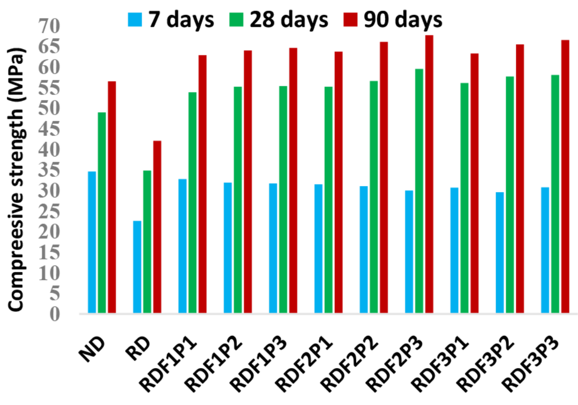

Figure 9. Results of mix-4's comp. strength

from 28 days to 6 months, which is consistent with [Exteberria et al., 2007]. They discovered that concrete containing 23% recycled aggregate had a 5% lower resistance value than natural aggregate concrete [Sagoe-Crentsil et al., 2001]. On the other hand, it was predicted that the compressive strength of a sample composed entirely of recycled aggregate would rise by 11% when compared to concrete made entirely of natural aggregate. However, when the natural aggregate replacement rate exceeds 30%, the compressive strength drops by 5% [Gomez Soberón, 2002]. Throughout the testing, the best combination was a 100% recycled aggregate alternative with RAC 0.5% steel fibre [Senaratne et al., 2015].

CONCLUSIONS

The physico-mechanical characteristics of RCA obtained from CC solved solid waste management by announcing the "RRR" principles, i.e., reduce, reuse, recycle, and point society's attention toward its prospective application. When compared to relevant characteristics of NAC concrete evaluation up to M30 at 28 days, test results show that PMSFRCC with SF 30 kg/m^3 and SBR latex 5% by cement weight improved typical strength in compression up to 6.63%. Nonetheless, compressive strength is enhanced by 9.98% and 11.30% for PMSFRCC with 30 kg/m^3 SF and 5% by cement weight SBR latex in M40 grade NAC at 28 and 90 days for PMSFRCC with 30 kg/m^3 SF and 5% by cement weight SBR latex in M40 grade NAC. When compared to NAC of the same grading, it demonstrates a significant increase in strength for high-quality concrete. When compressive strength is the basic prerequisite for concrete acceptance, PMSFRCC is more valuable. A mix of SF 30 kg/m^3 and SBR latex accounts for 5% of the weight of cement, PMSFRCC may surely be used for basic concrete. More research is focusing on CC with SF, and SBR latex is required to be used for purpose of large projects. These results revealed that when the degree of RCA usage is large, the cost is reduced by employing a large volume of CC, and it is conservative for R.C.C. buildings, abutments and piers, retaining walls, deck slabs, and so on. When natural aggregate is in short supply or unavailable for building, the aggregate derived from CC will prove to be a valuable asset to the construction projects.

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