Effectiveness Of Kadapa Marble Dust In Recycle Aggregate Concrete

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Abstract

Sustainability and availability of limited natural resources are few of the great concerns over the world. The concrete-jungle has occupied 2nd largest area after the water on the globe, but it is the time to look for alternatives for Ordinary Portland Cement. The manufacturing of 1 ton of cement can produce approximately same amount of CO_2 which causes huge global warming. In order to reduce these adverse environmental effects, the researchers were started research on replacing OPC partially or fully with supplementary cementitious materials such as fly ash, blast furnace slag, metakaolin, and marble-dust. The present study was aimed to focus on replacing Ordinary Portland Cement with Kadapa marble dust and natural aggregates with recycled concrete aggregates for sustainable infrastructure. The present article focused on evaluating the effect of replacing Ordinary Portland Cement with marble-dust at a replacement dosage of 0, 5, 10, 15, 20, 25 and 30% by weight of cement and replacing natural aggregates with recycled aggregates at a dosage of 0, 25, 50, 75 and 100%. Firstly, a set of recycled aggregate concrete mixes were prepared with different dosages (0, 0.1, 0.2, 0.3, 0.4 and 0.5% by weight of binder) of super absorbent polymer and an optimum dosage of this polymer was determined based on 28-days compressive strength. Secondly, a set of cubic specimens were prepared with marble dust and recycled aggregates and subjected to curing for 7, 14, 28, 60 and 90-days. Thirdly, the optimization of dosage of marble-dust was carried out based on 90-days compressive strength. Later, a relation between 28 and 90-days compressive strengths was developed using a simple linear regression analysis. In addition, the microstructural analysis was carried out using scanning electron microscope and X-ray diffraction and finally a dosage of 15% was recommended for marble dust to replace Ordinary Portland Cement for recycled aggregate concrete.

Keywords: recycled aggregates, marble-dust, super-absorbent polymer, compressive strength, optimization

1. Introduction

Environmental pollution and depletion of natural resources are being major concerns over the globe. In order to diminish environmental pollution, the researchers have been carrying out experimental studies and trying to provide environmental ecofriendly and sustainable construction solutions. In the construction field, the utilization of Ordinary Portland Cement can cause huge amount of carbon-footprint and the researchers focused on reducing carbon-footprint and cost by replacing it with secondary cementitious materials such as flyash, ground-granulated blast furnace slag (GGBS), metakaolin, silica-fume and marble-dust. In addition to it, in the recent few decades, the researchers have been trying to minimize the utilization of natural resources by replacing them with construction and demolition waste. With this background, the present study is aimed to evaluate effect of marble-dust and recycled concrete aggregates on properties of concrete.

The rate of generation of construction and demolition waste has been increasing day-by-day over the last few decades due to demolition of old concrete infrastructure. About 850 million tonnes of demolition waste being generated in the European Union every year, which represents 31% of the overall waste generation and an approximately 123 million tonnes waste being generated by USA [1]. Globally, a huge amount of concrete waste is derived from the demolition of antique concrete structures. Most usually this concrete waste is disposed in to landfills, hence inflicting sizable environmental load and health danger [1]. Furthermore, the shortage of land and the growing charges for landfills get worse this environmental annoy. The usage of concrete wastes in sustainable improvement might also alleviate such troubles. Sustainable improvement is currently a primary problem all around the globe. The concept of sustainable improvement was first provided in the year 1992 in an Earth Summit in Rio de Janeiro town of Brazil [2], and now it has turned out to be a guiding principle for the international construction enterprises. The recycling and reuse of concrete waste is one of the powerful techniques to obtain sustainability in construction field. Generally, aggregates occupy almost 70% of total concrete mix which can form main skeleton of the concrete [3]. A predominant portion of this aggregate extent is occupied through coarse aggregates. In order to meet this large requirement of aggregates to prepare concrete in huge quantity, a large quantity of natural aggregates is needed. But, the natural resources for acquiring natural aggregates were diminished due to construction of huge concrete infrastructure during last few decades. The shortage of natural aggregates and the increasing prices for landfill have additionally recommended the utilization of RCA in concrete infrastructure. Besides, the increased distance between the assets of fine natural aggregates and construction industry has restrained the contractors to substitute natural coarse aggregates by recycled concrete aggregates [4].

As the marbles become major construction material in concrete infrastructure from the ancient days [5], it has also become a great challenge for marble industries to dispose the marble-dust safely with low cost. A marble can be considered as a decorative construction material with varying mineral composition based on its sources [6]. The manufacturing of marble slabs can cause large amounts of waste and semi-processed marble slabs can also cause a waste of 2-5% [5]. Generally, these wastes can be categorized in to two categories such as solid and semi-solid waste [7]. Almost 30-45% of water is present in marble-slurry which will cause environmental (dust) pollution after drying and evaporation of water [8] and also contaminate agricultural fields [9], surface and ground water [10]. A recent study [11] revealed that the amount of marble dust will be increased in upcoming years to meet high requirements. In various countries such as India, Egypt, USA, Brazil, France and Portugal have a significant number of marble reserves and a state (Rajasthan) in India have 4000 marble mines and 100 marble processing units which will generate a huge of marble dust [12]. Few researchers studied the effect of strength gain or strength loss by replacing cement with marble dust at a dosage of 5 to 50% by weight of cement and few studies [13-18] reported a decrease in compressive strength and few other studies [19-25] reported increase in compressive strength of normal strength concrete corresponding to optimum dosage of marble dust.

Generally, the utilization of superplasticizers is becoming a part of a concrete mixes to improve the strength of concrete by reducing water-cement ratio. The reduction in water-cement ratio is causing shrinkage of concrete structures due to lower water content [26]. In order to reduce this shrinkage, the researchers have started using super-absorbent polymer to incorporate internal curing and reduce the autogenous shrinkage [27-30]. SAP is a polymer material having a three-dimensional hydrophilic network structure, which can capable of absorbing and storing the water by hundreds to thousands of times by their dry weight [31-33]. During the process of hydration and evaporation of water, this polymer can capable of providing inner water continuously to compensate inner moisture-loss. With this background, the present study was aimed to focus on evaluating the compressive strength of concrete specimens incorporated with super-absorbent polymer, Kadapa marble dust and recycled concrete aggregate

2. Materials and Methodology

Ordinary Portland Cement of 43 grade conforming to IS standards has been used, and the following tests have been carried out according to IS: 8112 – 1989. In this study, white colored super absorbent polymer (SAP) was obtained from the suppliers of Matrix industries, and it is mainly designed for use in Agriculture and Horticulture. The size of this polymer was ranged between 0.075-2.30mm and the corresponding visible and microstructure was depicted in following Figure 1.

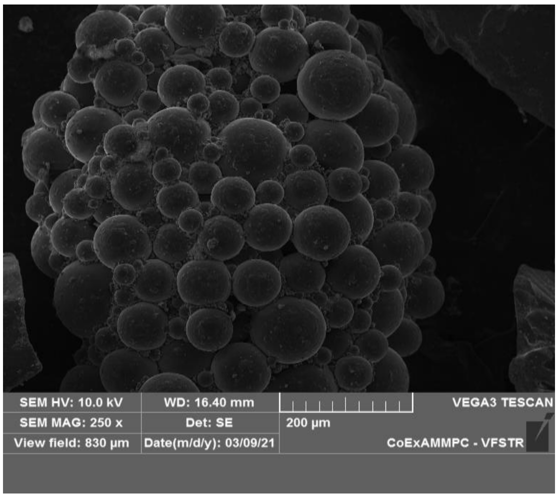


Figure 1 SAP with naked eye (left) and its microstructure from SEM (right)

Table 1: Properties of Ordinary Portland Cement

Test	**Results**	**Specification value (IS: 8112 – 1989)**
Fineness	5.2%	<10.0%
Specific gravity	3.10	--
Normal consistency	32%	--
Setting time (**minutes**)		
Initial	42	Min 30
Final	428	Max 600
Compressive Strength (**MPa**) at		
3 days	25.20	23.0
7 days	36.30	33.0
28 days	45.80	43.0

In this study marble dust was obtained from the slab polishing industry, where the waste is being generated from the polishing of Kadapa slabs. The dry powder (Kadapa marble dust) was collected from the industry, and it was sieved through a 90micron pan. The chemical composition of Kadapa marble dust was presented in Table 2. In addition, the microstructure of Kadapa marble dust was depicted in Figure 2.

Figure 2 Kadapa marble dust (left and its microstructure from SEM (right)

Table 2: Chemical composition of marble dust

Element	**Weight (%)**
Calcium	44.43

Silica	7.99
Carbon	3.28
Aluminum	1.25
Potassium	0.82
Sulphur	0.29
Magnesium	0.16
Iron	0.05
Sodium	0.04
Oxygen	41.69

In this study, a set of 15cm cubic specimens were prepared with super absorbent polymer at a dosage of 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5% by weight of cement; recycled concrete aggregates at a replacement dosage of 0, 25, 50, 75 and 100% by weight of total aggregates. Firstly, these specimens were subjected to 7-days water curing and 21-days air-curing. These 28-days cured specimens were subjected to compression test and the dosage of SAP was optimized based in this 28-days compressive strength. Secondly, a set of 15cm cubic specimens were prepared with Kadapa marble dust by replacing OPC at a dosage of 0, 5, 10, 15, 20, 25 and 30% by weight of cement at an optimum dosage of SAP. Later, these specimens were cured for 7-days in water and then air-cured. For 7, 14, 28, 60 and 90-days compressive strengths were evaluated. A linear relation between 28-day and 90-days compressive strength was developed. Finally, the microstructure of control mix and the recycled aggregate concrete mix with Kadapa marble dust at optimum dosage was studied using Scanning Electron Microscope (SEM) and X-ray diffraction (XRD).

3. Results and Discussion

Optimization of SAP-dosage

28-day compressive strengths of 15cm cubic specimens cured for 28-days as aforementioned steps were presented in Figure 3. It was observed that an increasing trend was noticed up to 0.2% SAP-dosage in 28days compressive strength and after that, a declining trend was observed with further increment in SAP dosage. Hence among all mixes, 0.2%SAP mixes exhibited superior performance in terms 28days compressive strength. The maximum strength of these specimens was indicated by a line of optimum SAP-dosage in the following plot.

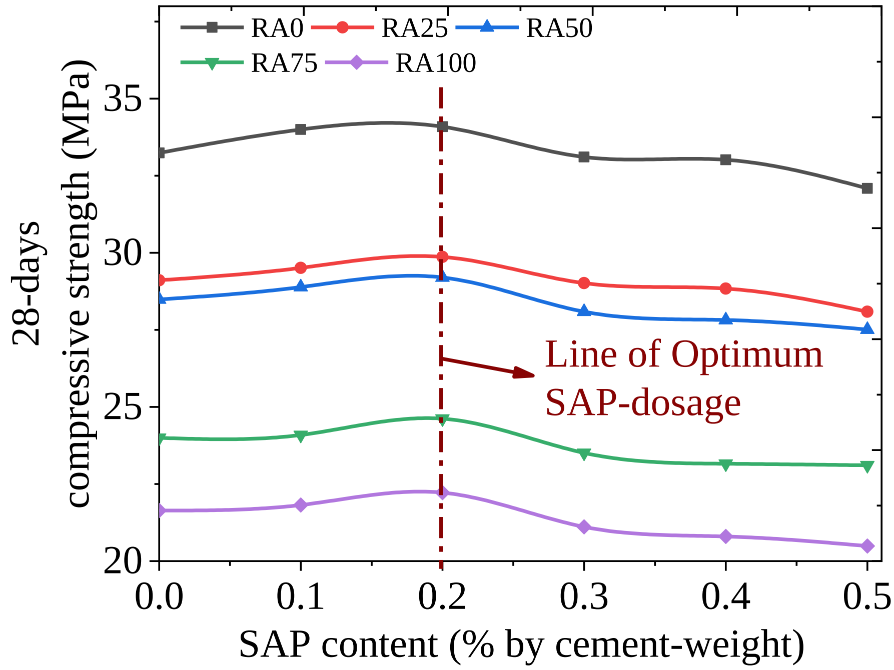
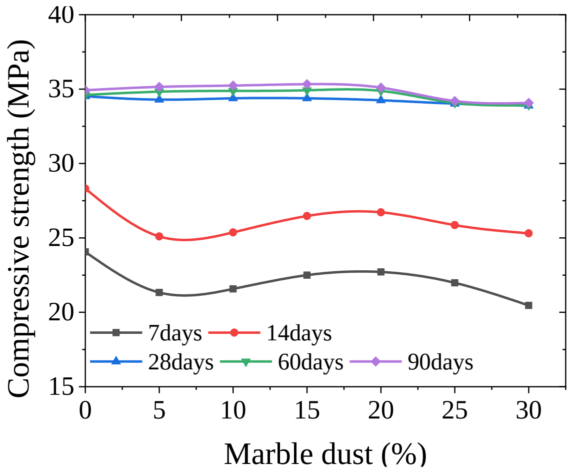


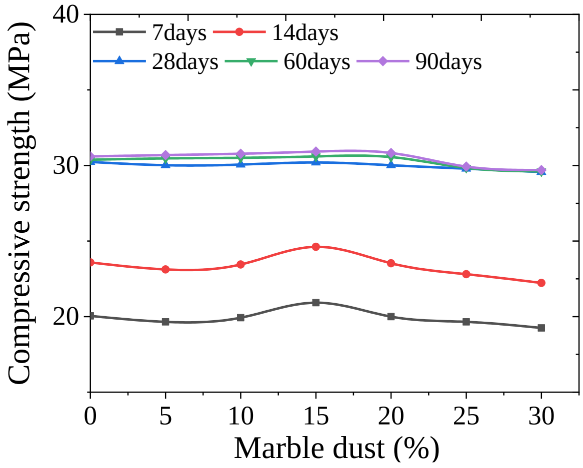
Figure 3 Optimization of SAP-dosage based on 28-days compressive strength

From the Figure 3, it was clear that maximum 28days compressive strengths were achieved at a dosage 0.2% SAP for all the mixes with different proportions of recycled concrete aggregates mix which indicates that optimum dosage of SAP is 0.2%, hence further research is carried forward with 0.2%SAP only.

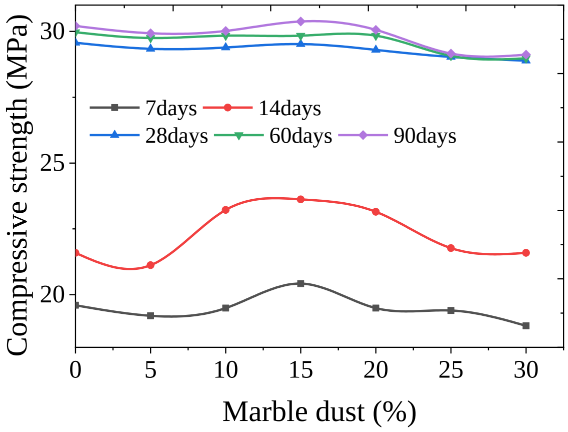
Compressive strength of recycled aggregate concrete with Kadapa marble dust

In this section, the compressive strength of cubic specimens cured for 7, 14, 28, 60 and 90-days were discussed through a set of non-linear curves plotted between compressive strength and marble dust for a specified curing period.

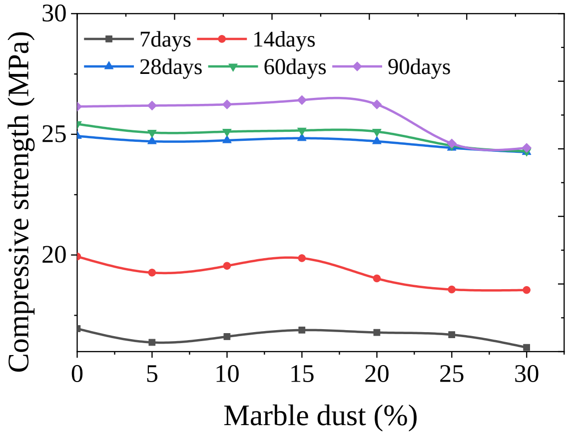




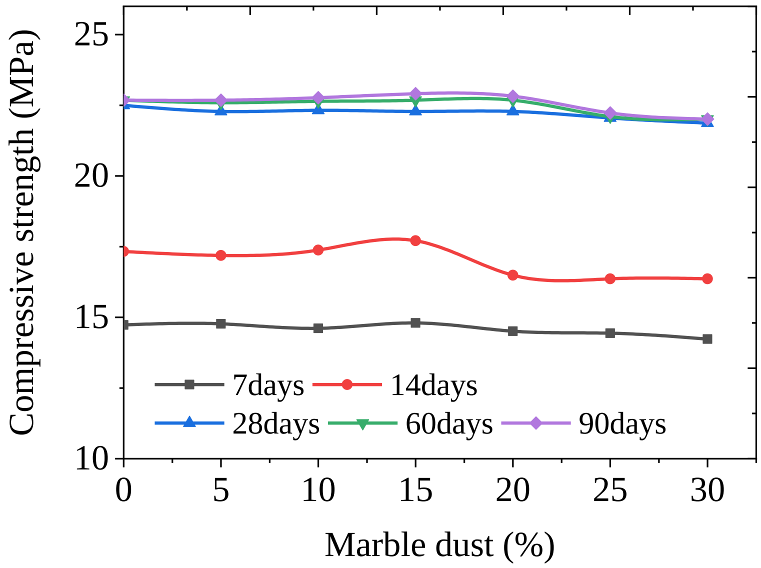
a. Mixes with 0% recycled aggregates



b. Mixes with 25% recycled aggregates



c. Mixes with 50% recycled aggregates



d. Mixes with 75% recycled aggregates

e. Mixes with 100% recycled aggregates

Figure 4. Variation in compressive strength with dosage of Kadapa marble dust and curing period

The variation in compressive strength of specimens prepared with 0, 25, 50, 75 and 100% recycled aggregates with increase in Kadapa marble dust was presented separately in the Figure 4. In case of mixes without recycled aggregates, maximum compressive strengths were observed as compared to those of mixes with recycled aggregates. A maximum compressive strength of 24.1MPa, 28.3MPa, 34.5MPa, 34.6MPa and 34.9MPa were observed for 7, 14, 28, 60 and 90-days cured specimens prepared without recycled aggregates and marble-dust (reference mixes). As the replacement-dosage of marble-dust increased, the compressive strength was also increased up to a dosage of 15% and started declining beyond a dosage of 15%. In case of mixes with marble-dust and without recycled aggregates, a maximum 28-day compressive strength of 34.38MPa was observed at a replacement dosage of 15% of marble dust. In all the mixes, the rate of increase in compressive strength was observed more between a curing period of 7 and 14days; 14 and 28-days as compared to the rate of strength-gain between 28 & 60-days; 60 & 90-days. Hence, the compressive strength lines for specimens cured for 28, 60 and 90-days were aligned closely as compared to the strength-lines corresponding to specimens cured for 7, 14 and 28-days. It was also observed that the variation in 60 and 90-days compressive strength beyond 25% of marble-dust found to be negligible.

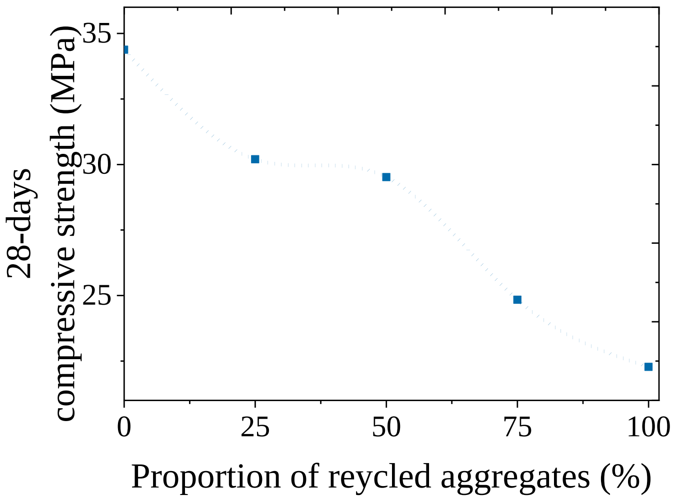


Figure 5. Variation in 28-days compressive strength with proportion of recycled aggregates for the mixes with 15% (optimum dosage) marble dust

In order to optimize dosage of marble dust, 28-days compressive strength was considered. In overall, a maximum 28-day compressive strength of 34.38MPa, 30.2 MPa, 29.52 MPa, 24.84 MPa and 22.28MPa was observed for cubic specimens prepared with 0, 25, 50, 75 and 100%; and 15% marble dust. Hence, a dosage of 15% marble dust was considered as optimum dosage and corresponding variation in 28-days compressive strength with increase in proportion of recycled aggregates for mixes was presented in Figure 5. From the results, a declining trend in compressive strength was observed with increase in proportion of recycled aggregates.

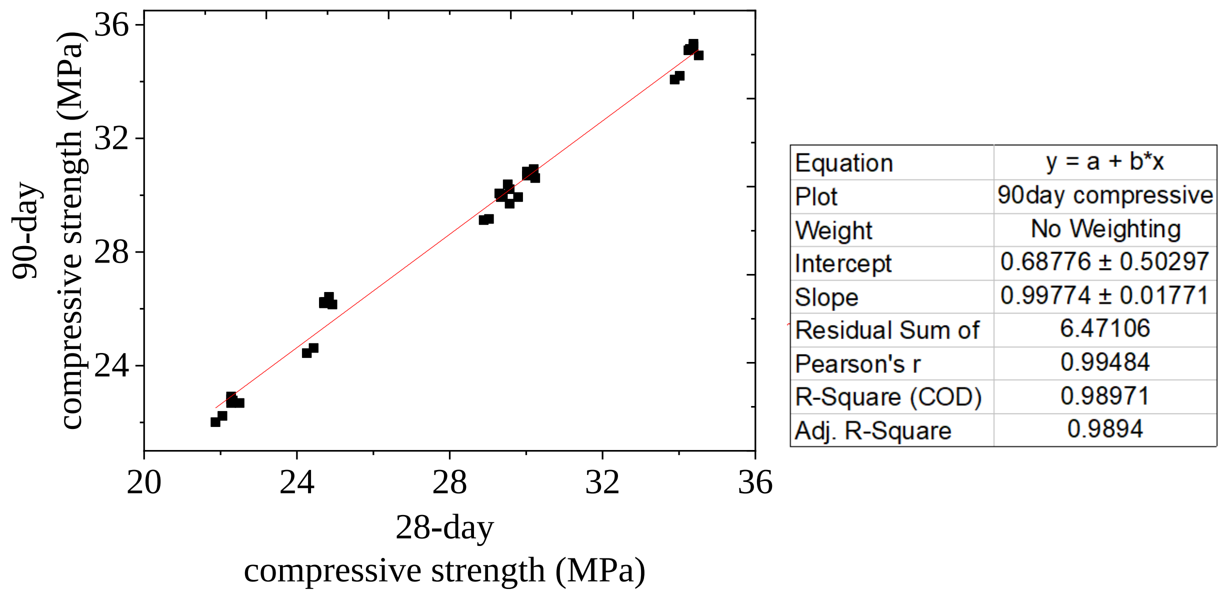


Figure 6. Relation between 28 and 90-days compressive strength

In addition, a relation between 28 & 90-days compressive strength was developed for recycled aggregate concrete with Kadapa marble dust. In order to develop this relation, a total of 35 datapoints for each strength were considered. A simple linear regression analysis was carried out and a good correlation was found between these two strengths with an R-square value of 0.9894 Figure 6.

Microstructural Analysis

In this study, the microstructure of the reference mix (after 28-days of curing), a mix with 0.2%SAP (28 days-aged) and a mix with 0.2%SAP+15%KSW+RC50 (90 days-aged) was captured by using scanning electron microscope. In addition, the chemical compositions of these mixes were analyzed using XRD. In general, the effect of admixtures used in the cement composites can be fully effective after an age of 90 days, hence, the microstructure of 15% marble-dust incorporated recycled aggregate mix (50% RA) cured for 90 days was considered for was taken to assess the effectiveness of marble-dust in the process of strength-gain. The chosen samples were examined with XRD and SEM techniques and images of them presented from Figure 7 to 9.

From Figure 7 (a), (b) and (c), it was revealed that the presence of compounds such as CSH, C_2S and C_3S were considered as responsible for higher compressive strength. In addition, micrographs (Figure 7(a) and Figure 7(b)) revealed few voids and CH compounds in the microstructure of reference specimen, and hence, there may be chances of formation of CSH gel from the existing CH-compound by adding further pozzolana material.

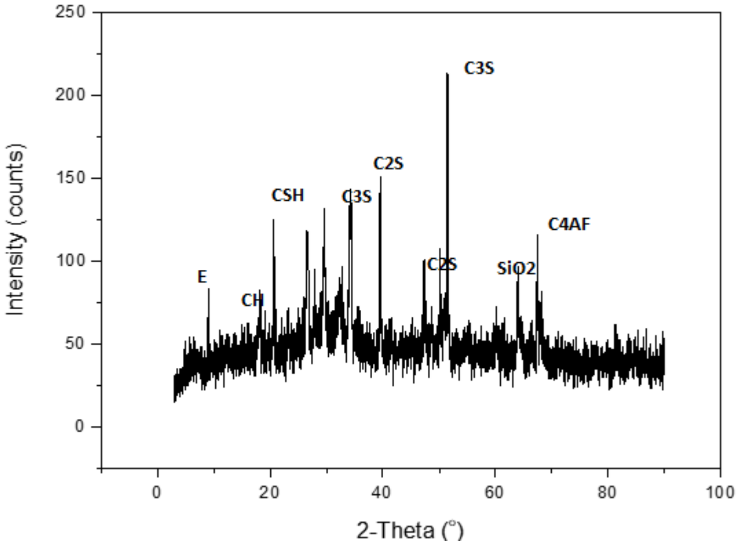


Figure 7 (a) XRD pattern for reference sample (28 days age)

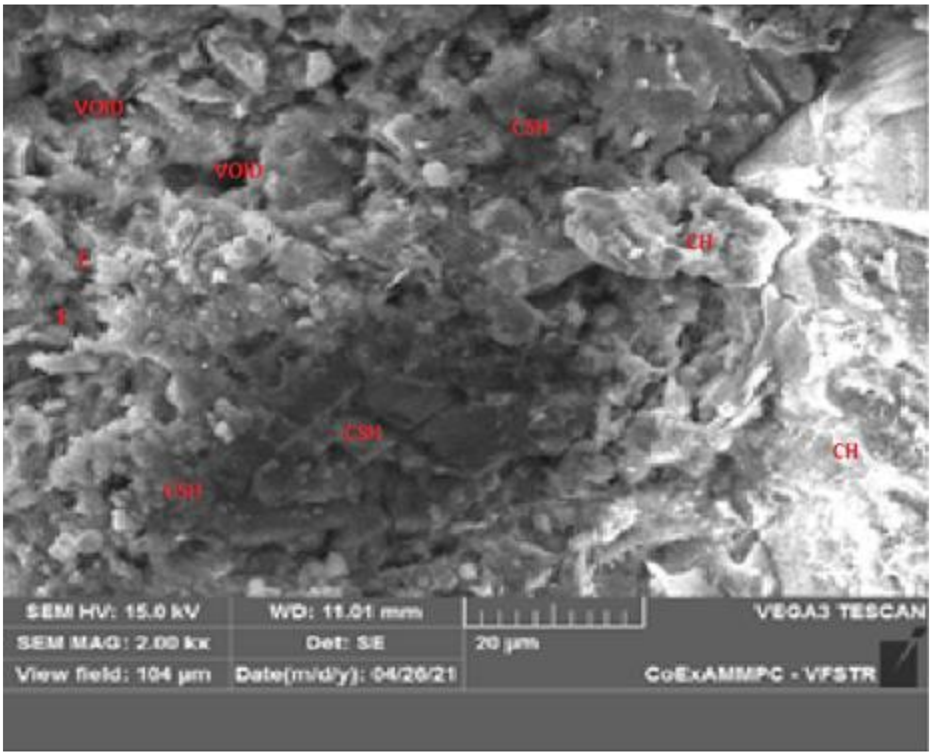


Figure 7 (b) SEM image for reference sample (28 days age)

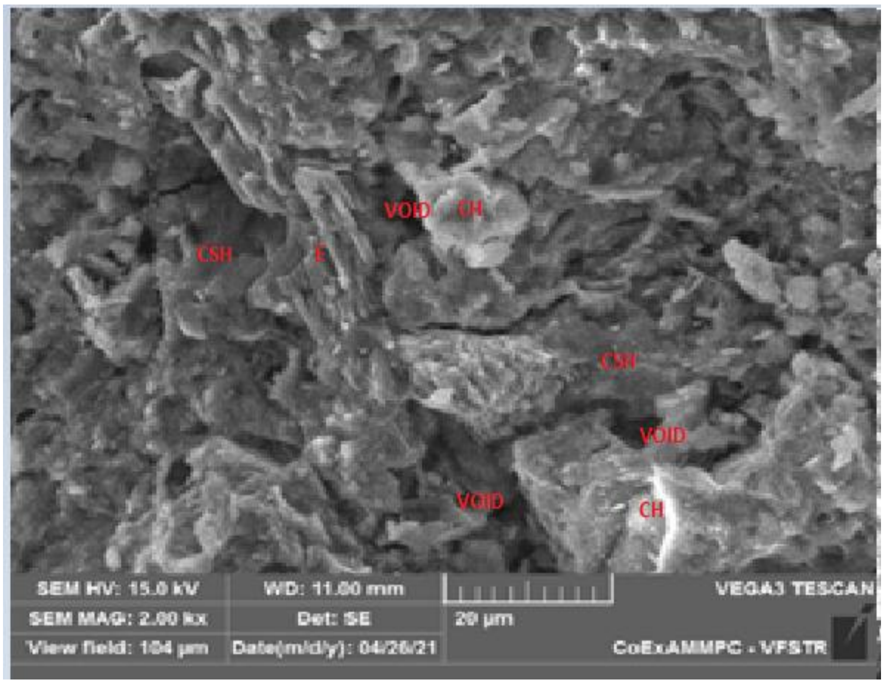


Figure 7 (c) SEM image for reference sample (28 days age)

From Figure 8 (a), (b) and (c), the XRD-plots revealed more intensity for aforementioned compounds which would indicate the effect of 0.2%SAP. In these mixes, super absorbent polymer released water (during hydration process) to the mix more or less uniformly and caused an enhancement in compressive strength.

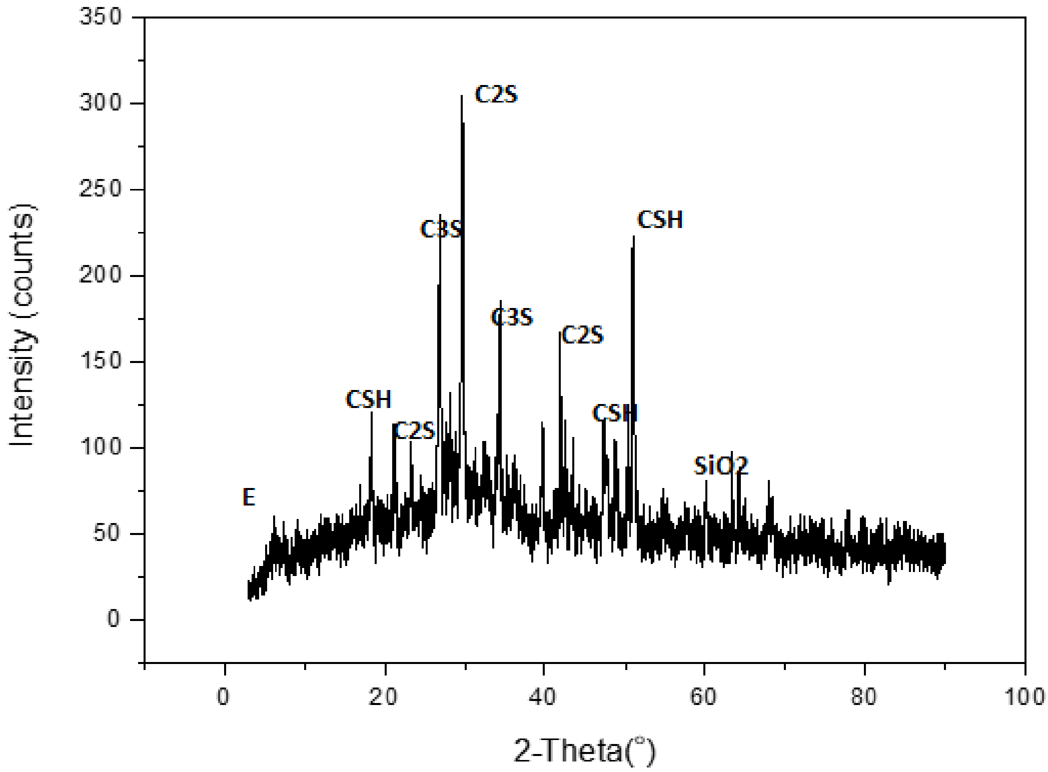


Figure 8 (a) XRD pattern for 0.2% SAP sample (28 days age)

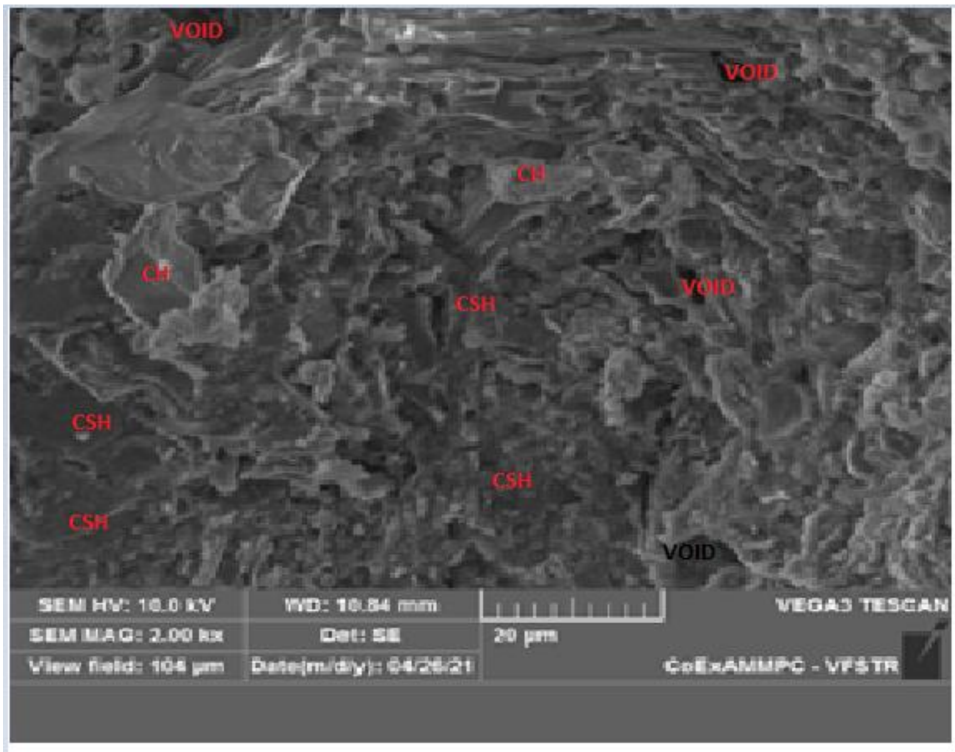


Figure 8 (b) SEM image for 0.2% SAP sample (28 days age)

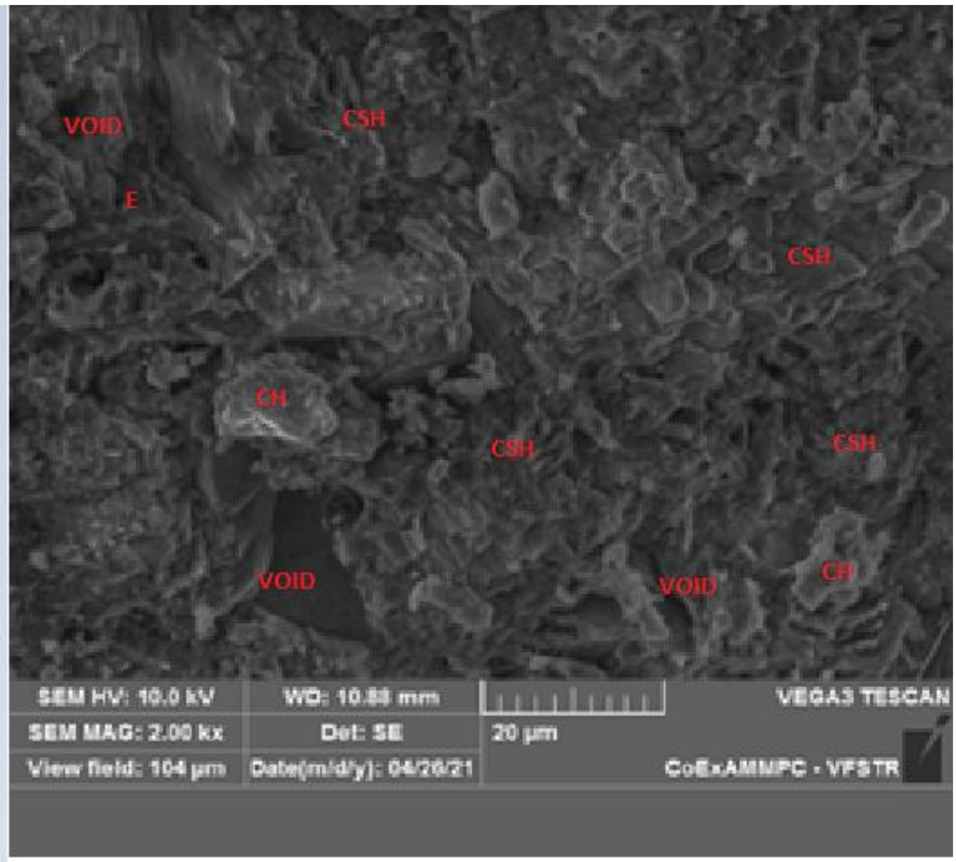


Figure 8 (c) SEM image for 0.2% SAP sample (28 days age)

From Figure 9 (a), (b) and (c), the effect of 15% Kadapa marble dust in addition with 0.2%SAP was revealed in terms of micrographs and XRD intensities. In this mix, Kadapa marble dust was reacted with residual CH which led to enhancement in the strength and it was clearly visible after 90 days of curing. From the Figure 9(a), higher intensity was observed for the strength responsible compounds such as CSH, C_2S and C_3S as compared the previous two cases. Hence it was considered as main reason to attain the higher strengths than the references and 0.2%SAP samples. The availability of CH was not sufficient to react with marble-dust beyond 15% and formed an inert material in the matrix which ultimately led to declination of compressive strength.

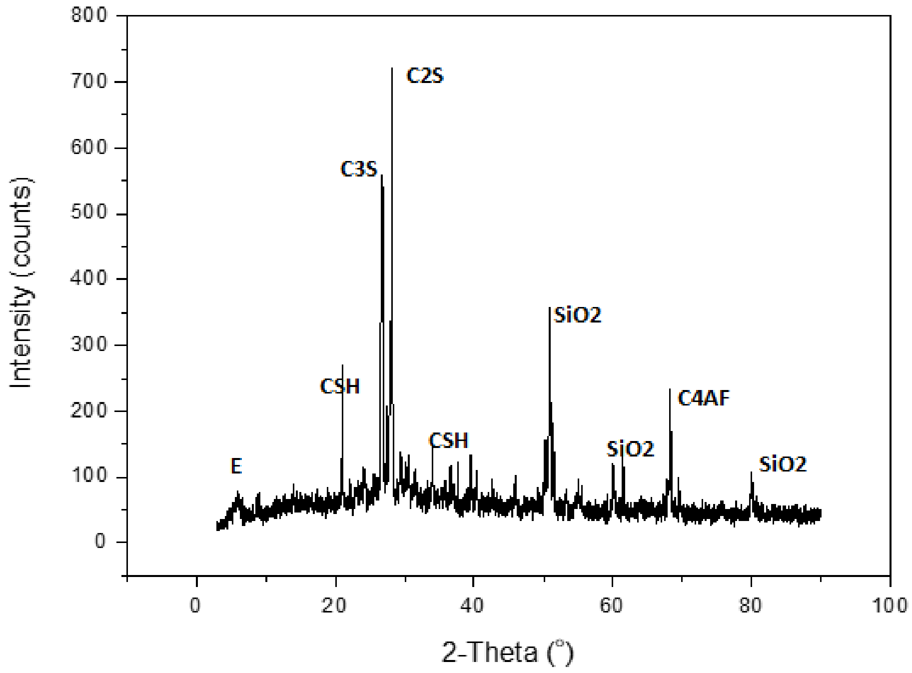


Figure 9 (a) XRD pattern for 0.2% SAP+15%KSW+50RAC sample (90 days age)

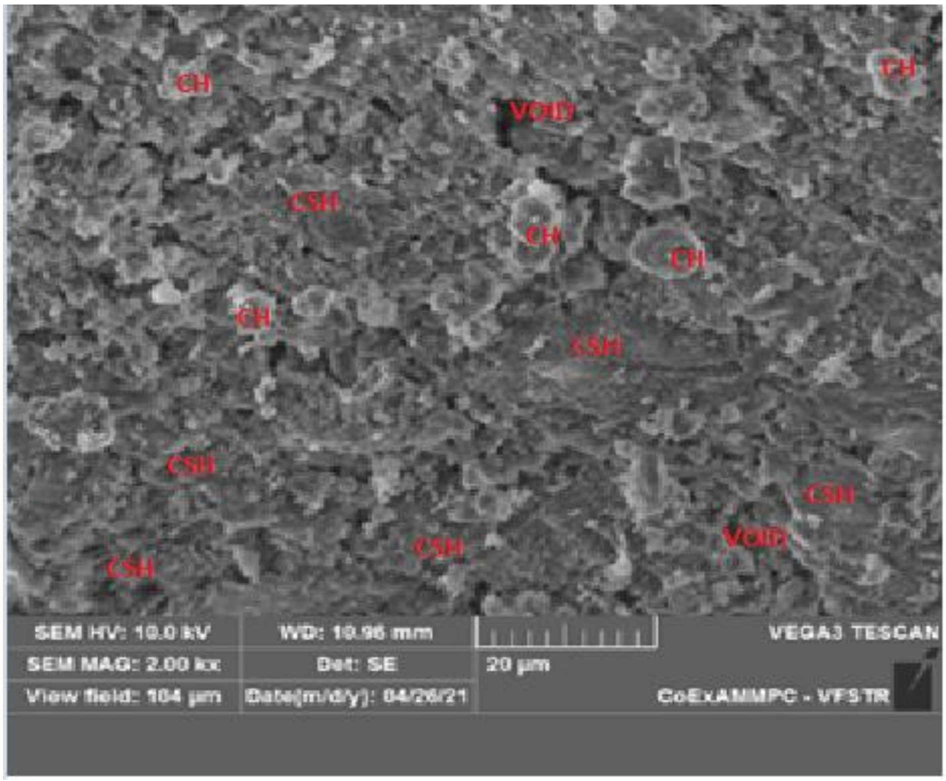


Figure 9 (b) SEM image for 0.2%SAP and 15%KSW sample (90 days age)

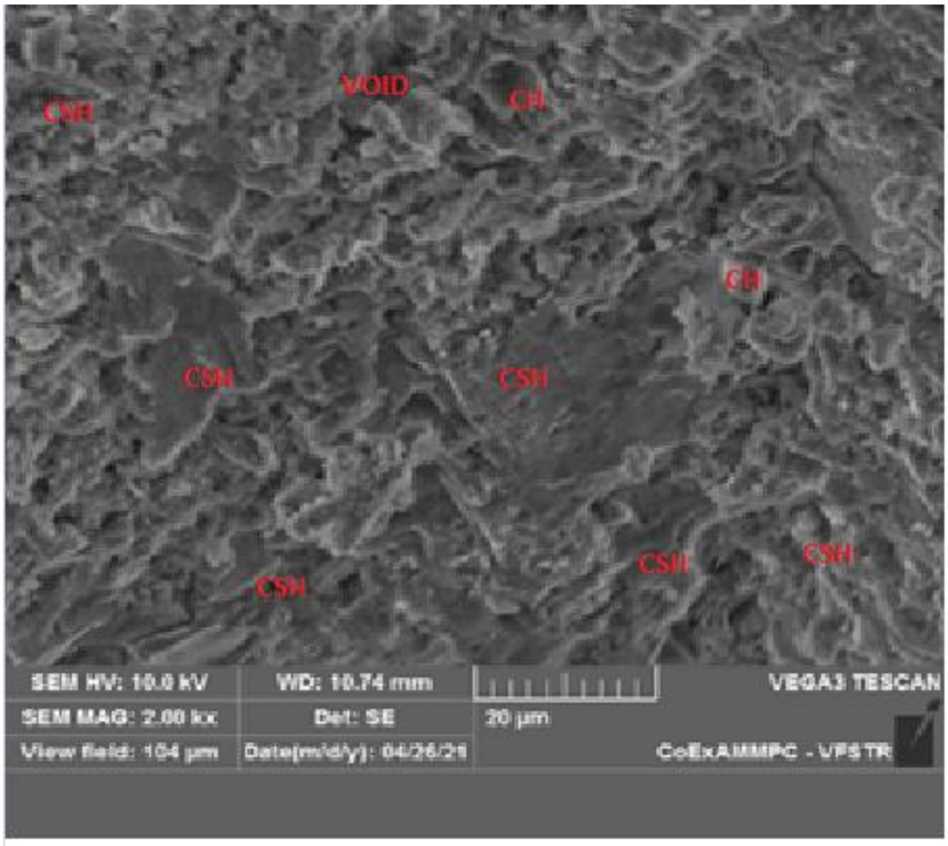


Figure 9 (c) SEM image for 0.2%SAP and 15%KSW sample (90 days age)

4. Conclusions

The present article presented the optimization of Super Absorbent Polymer for recycled aggregate concrete based on 28-days compressive strength. Later, the effect of replacing Ordinary Portland Cement with Kadapa marble dust on compressive strength of recycled aggregate concrete was evaluated. The microstructural analysis was carried out using Scanning Electron Microscope (SEM) and X-ray diffraction (XRD). From this study, following conclusions were drawn.

- An optimum dosage of Super Absorbent Polymer (SAP) was evaluated based on 28-days Compressive strength and corresponding value was reported as 0.2% by weight of cement for all recycled aggregate mixes.
- A decreasing trend in Compressive strength was observed with increase in proportion of recycled concrete aggregates
- An optimum replacement dosage of Kadapa marble dust was determined based on 90-days Compressive strength and the corresponding value was reported as 15% by weight of cement.
- The unavailability of sufficient CH to react with marble-dust beyond 15% was caused decrease in Compressive strength due to formation of inert materials instead of CSH gel.

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