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Research Article

Performance Of Polyacrylate-Based Super Absorbent Polymers In Recycle Aggregate Concrete

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ARTICLE INFO	ABSTRACT

This article presents the super absorbent polymer (SAP) performance in recycling aggregate concrete. In conventional concrete the coarse aggregate is replaced with recycle aggregate in the proportion varying from 0,25,50,75 and 100%. The mix with 0%RA is considered as reference or control concrete. The SAP was added as to all recycle aggregate concrete (RAC) mixes by weight of cement in the proportion ranging from 0.1,0.2,0.3,0.4 and 0.5%. The significance of the SAP in RAC was studied based on compressive strength of cube and its behaviour is studied at 7, 14 and 28 days and the analysis is supported with SEM images. At all stages the strengths are compared with control concrete, and it was found that 0.2% SAP is effective for all RAC mixes.

Key words: SAP, RA, RAC, Compressive Strength, Mix proportion

1. Introduction

Re-utilization of demolition waste is essential to improve the sustainability in concrete industry and to conserve the nonrenewable natural resources[16][17]. The large-scale use of demolition waste in new construction also contributes to the control over construction demolition waste, which is often a problem in cities. Recycled Aggregate (RA) is a valuable substitute to natural aggregate, which helps within the upkeep of the environment[1]. The diversity of aggregate family is one of the critical parameters that affects the usage of RA[1][18]. However, the material supplied to the recycling unit for RA production greatly influences the quality of RA[19]. Therefore, in view of current limitations on recycling units it is very difficult to produce affordable and quality RA.

Many researchers[2][3][4] observed that water absorption increases as the strength of the parent concrete increases and it also decreases with increasing maximum size of aggregate (MSA). Previous literature reported that resistance to mechanical actions, namely crushing, abrasion and impact of recycling aggregates are less compared to fresh granite aggregates. Resistance to mechanical action decreases with a decrease in the MSA.

In modern polymer technology, Superabsorbent polymers (SAPs) are the most fascinating materials, which absorb water. This beneficial effect of SAP has also been adopted in concrete technology. Since internal curing is considered to be one of the most effective methods to prevent concrete cracking, the ability of SAP to absorb, retain and release water when conditions change is beneficial. Considering the importance of SAP in internal curing of concrete, most of the research studies have been carried out to investigate its effect on mechanical and durability properties of cement and concrete matrix. The predominant aim of the current research is to examine the super absorbent polymer (SAP) in different proportions of weight of cement. Piérard et al.[5] investigated the strength of the concrete with the SAP contents of 0.3 wt% and 0.6 wt% of at various ages. The test results indicated that the strength at 28 days is 7% and 13% lowered than that of normal mix. Esteves et al.[6] observed the decreased compressive strength of 15-20% in SAP-modified mortar specimens with 0.3 wt% SAP than that of nominal mortar mix specimens with 0 wt% SAP. Pourjavadi et al.[7] investigated the compressive and flexural strength of SAP modified cement pastes made of SAP contents 0 wt%, 0.1 wt% and 0.3 wt% of the binder, and subjected to lime water and room temperature curing. Although the compressive and flexible strength values decreased during lime water curing, it was clear from the results that the strength values increased at room temperature curing.

From the studies conducted on SAP-modified mortar specimens with SAP contents of 0 wt%, 0.2 wt%, 0.4 wt%, and 0.6 wt%, Beushausen et al. [8] reported that no significant change in compressive strength in SAP-modified specimens compared to control mortar specimens. However, Beushausen et al. [8] also reported that although the strength decreased with SAP at early period, but recovered over time resulting from ongoing hydration facilitated by internal curing. Beushausen et al. [8]was reported the positive effect of SAP on tensile strength at w/c while the negative effect was observed at w/c 0.55. Mignon et al.[9] reported that the addition of SAP content of 0.5 wt% and 1.0 wt% in mortar mixture didn't show any significant difference in flexural strength but the compressive strength decreased compared to control mix. The results of Bentz et al. [10]studies conducted on SAP-modified mortar specimens with SAP content of 0.4 wt% reported that although the compressive strength was lowered at 7 days but at 28 days the values were 1.2 times higher than that of control mortar specimens. The studies of Yao et al. [11]suggested that the inclusion of SAP significantly increased the tensile strength and ductility, but that it significantly reduced the compressive strength. The investigations of Wu[12] showed that incorporation of SAP can reduce the autogenous shrinkage of concrete, but SAP content in concrete drastically reduced the compressive strength of concrete. Although the advantage of SAP in the initial shrinkage of concrete is commendable, the negative effect of SAP on the strength of concrete cannot be ignored [13].

From the literature [1–4,6,14,15]it has been observed that the effect of SAP on mechanical strength properties is not yet clear. While some researchers have reported a positive effect of SAP on mechanical properties, some researchers have reported an adverse effect due to the increased pores caused by the inclusion of SAP, which reduces mechanical properties. Moreover, some researchers have reported no significant increase or decrease in mechanical strength variation with SAP compared to the control mixture.

Concerning the recycled aggregate, from the above discussion it is well understood that the recycle aggregates possess adhering mortar and it led to more porous nature. This texture dominates water absorption than the fresh granite aggregate. Due to the porous nature of RA water obstruction is more and it causes difference in water quantity for real requirement of concrete, finally it led to strength loss. Therefore, it could be expected that the inclusion of SAP and recycled aggregate concrete will affect the internal water demand and thereby affect the internal curing.

In the present work, the combined effect of SAP and recycled aggregate concrete on compressive strength of concrete has been investigated. For this investigation the concrete specimens were prepared with recycled aggregate and the SAP content varied from 0.1 to 0.5 wt% with an increment of 0.1 wt% of cement.

2. Experimentation

For the experimental investigation, a total of 270 concrete cubes of size 150x150x150mm are cast and subjected to compression test at the ages of 7, 14 and 28 days. The main variables of the present study are different doses of SAP and RA. The fresh granite aggregate has been replaced with RA in the proportions of 0%, 25%, 75% and 100% respectively. SAP has been added as an additive to all mixes in the various dosages of 0.1, 0.2, 0.3, 0.4 and 0.5 wt% by weight of cement. The concrete mixtures made with ordinary Portland cement (OPC) of grade 43, natural granite coarse aggregate, recycle aggregate (demolition of aged building), manufacture sand, laboratory potable water, and superplasticizer. The quantity of materials for various concrete mixtures per one cubic meter is presented in Table 1. After 24 hours of casting, the concrete cube specimens were subjected to water curing for seven days and then exposed to an open atmosphere for fourteen days.

Table 1: Mix proportions

% of RA	Specific gravity	% WA	Dry rodded weight kg/cum	w/c	Cement (kg)	Fine aggregate (kg)	NCA (kg)	RCA (kg)	Mixing water (Lit)	Extra water added (Lit)
0	2.66	0.53	1520	0.44	418.20	840.18	912.00	-	184	0.97
25	2.63	1.42	1488	0.44	418.20	849.12	669.60	223.20	184	2.61
50	2.61	2.30	1456	0.44	418.20	861.70	436.8.	436.80	184	4.23
75	2.58	3.20	1424	0.44	418.20	871.40	213.6	640.80	184	5.88
100	2.56	4.08	1392	0.44	418.20	884.00	-	835.20	184	7.45

3. Results and Discussions

3.1 Effect of Super Absorbent Polymer

Table 2 shows the compressive strength results of the specimens made of different dosage levels SAP and RA at the ages of 7,14 and 28 days. The discussion of the test results is made with respected to 7, 14 and 28 days individually and furnished below in different sub sections

3.1.1 At the age of 7 days: In the case of 0% SAP, the concrete mixtures made of 0,25,50,75 and 100% replacement levels of recycled aggregate showed the 7th day compressive strength of 20.28, 18.34,18.23,14.88,13.20 MPa respectively. Increasing the SAP from 0 to 0.1% slightly increased the 7th day compressive strength in RA0, RA75 and RA100, while decreasing it in the RA25 and RA50 specimens. From the 7th day compressive strength results, it has been observed that the rise in SAP dosage from 0 to 0.1% didn't show a clear trend. Similar inconsistent 7th day compressive strength results have been observed in specimens of SAP dosages 0.2,0.3, and 0.4% compared to the specimens made with 0% SAP. However, in the case of SAP dosage of 0.5%, 7th day compressive strength has been almost decreased compared to the specimens made of 0% SAP. Although reduced results have been observed with increasing the SAP dose in some mixtures compared to 0% SAP, the increased trend in some other mixtures has a vague effect of SAP on 7th day compressive strength.

3.1.2 At the age of 14 days: While observing the 14th day the compressive strength of 0% SAP, for RA0 specimens the compressive strength is 26.92Mpa. With an increase of 0.1, 0.2, 0.3 0.4, and 0.5% SAP, 14th day compressive strength decreased to 24.82, 24.54, 25.16, 25.76, and 24.39 respectively. It means that in RA0 specimens, 14th day compressive strength decreased with increasing SAP content. Moreover, the effect of SAP on 14th day compressive strength is also not clear in recycled aggregate concrete mixtures namely RA25, RA50, RA75 and RA100. Similar inconsistent compressive strength results were also observed at 7 days of age.

3.1.3 At the age of 28 days: The 28 days compressive strength results of the specimens made of different dosage levels SAP and RA have been shown in Figure 1. The same results were also tabulated in Table 1. In the case of RA0 specimens, the raise in SAP dosage from 0 to 0.1 and 0.2% increased the 28th day compressive strength compared to those made of 0% SAP. The increased percentage of 28th day compressive strength of RA0 with 0.1 and 0.2% are 2.29 a 2.56% respectively compared to those made of 0% SAP. In contrast further increases of SAP i.e., 0.3, 0.4 and 0.5%, reduced the compressive strength of RA0 specimens compared to those made with 0% SAP. The decreased percentages of RA0 with 0.3, 0.4 and 0.5% SAP are 0.39, 0.66 & 3.46% respectively compared to those made of 0% SAP. While observing the influence of SAP on RA25 specimens, the increased SAP from 0 to 0.1 and 0.2% increased the 28th day compressive strength in the percentages of 1.37 and 2.61% respectively. As observed in the case of RA0, the RA25 specimens also decreased the 28th day compressive strength of percentage 0.31, 0.93 and 3.5% for the SAP dosages of 0.3, 0.4 and 0.5% respectively.

For RA50 specimens, comparing the 28th day compressive strength of 0% SAP with those made of 0.1 and 0.2% SAP the percentage of increments are 1.40 and 2.49% respectively. But the percentage strength decrements of SAP dosages of 0.3, 0.4 and 0.5% specimens are 1.40, 2.35 & 3.44% respectively compared to 0% SAP. For RA75 specimens, the increased SAP dosage from 0 to 0.2% increased the 28th day compressive strength from 24 MPa to 24.62 Mpa, while in further increment of SAP dosage up to 0.5% the strength gradually decreased to 23.11 MPa. This means that with the SAP increased from 0 to 0.2%, the 28th day compressive strength of RA75 specimens increased to approximately 2.18%, which decreased to 3.71% when the SAP was increased to 0.5%. For the RA100 specimens, the SAP dose increased from 0 to 0.2%, while the cube compressive strength increased by 2.68% compared to 0% SAP. However, in the case of RA100 models with 0.3, 0.4 and 0.5% SAP, the 28th day strength reduction percentages are 2.45, 3.88 & 5.31%, respectively. From Figure 1, a slight increase on the 28th day compressive strength can be observed from 0 to 0.2% SAP, followed by a declining trend up to 0.5% SAP in all concrete mixes.

From the above discussion it is clear that the effect of SAP on 7th day and 14th day compressive strength is not clear, but a clear trend can be observed in the 28th day results. This might be due to the reason that the first 7 days the specimens were exposed to water curing in which period SAP doesn't participate actively. After the 7 days of water curing, the specimens were exposed to ambient temperature for 14 days. It means that at the age of 14 days (7 days wetting+7 days drying) the SAP could be partially participated. After 14 days of drying (i.e., 7 days wetting +14 days drying) the SAP could participate actively in the hydration process and thus increase the strength of concrete.

From the 28th day compressive strength results, it is clear that the increase in SAP content from 0 to 0.2% increased the compressive strength of concrete cube specimens. Moreover, after the 0.2% SAP increment the 28th day compressive strength gradually decreased. Figure 2(a) and Figure 2(b) depict the X-ray diffraction (XRD) map and Scanning Electron Microscope (SEM) image of RA0 specimen made of 0% SAP respectively. In Figure 2(a) and Figure 2(b), the traces of calcium silicate hydrate (CSH), Dicalcium silicate (C_2S) and tri calcium silicate (C_3S) can be found. From SEM image of RA0 specimen with 0% SAP voids and calcium hydroxide (CH) compound also noticed a few places. The CH compound may also form additional CSH gel.

Figure 3(a) and Figure 3(b) depict the XRD and SEM image of RA0 concrete specimen made of 0.2% SAP. As shown in Figure 3(a) and Figure 3(b), the traces of CSH, C_2S, and C_3S are also available in the specimens made of 0.2% SAP. However, it is also observed that compared to 0% SAP, the earlier said compound are available with more intensities compared to 0.2% SAP, which indicates the enhancement in strength. This can be attributed to the water released by the SAP during hydration process.

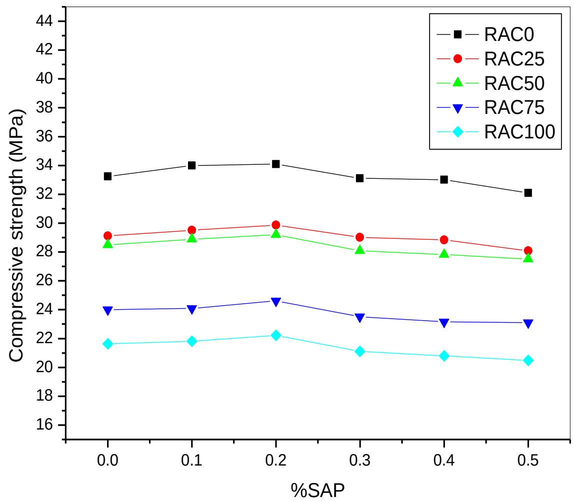

Figure 1: 28th day Cube compression Vs SAP %

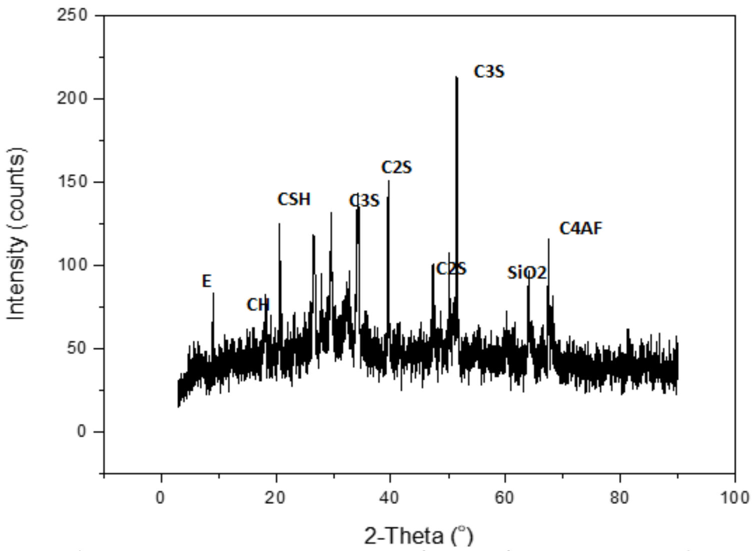

Figure 2 (a): XRD pattern for Reference sample (0%SAP)

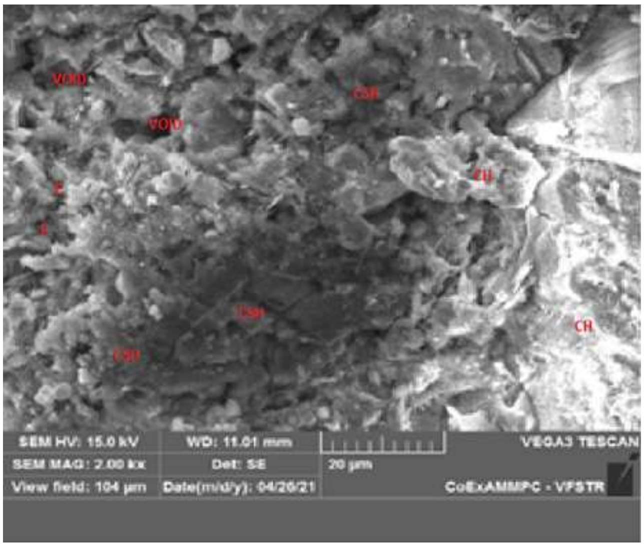

Figure 2(b): SEM image for Reference sample (0%SAP)

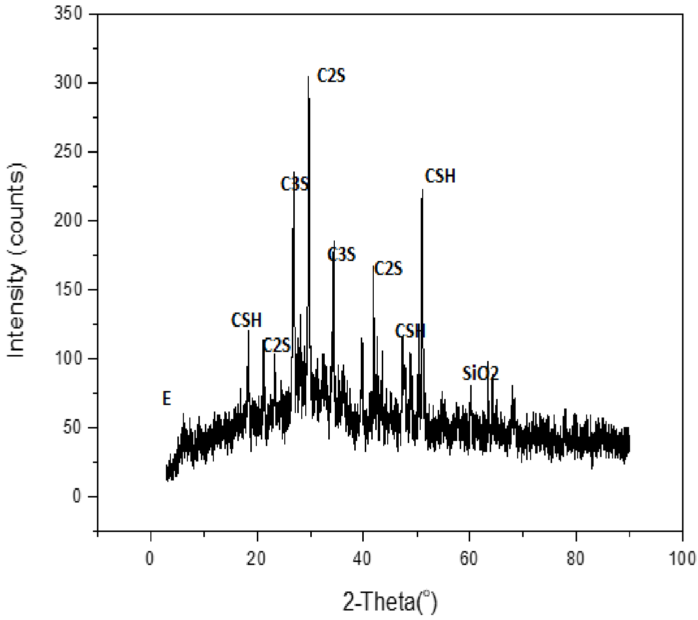

Figure 3 (a):28 days XRD pattern for 0.2%SAP mix

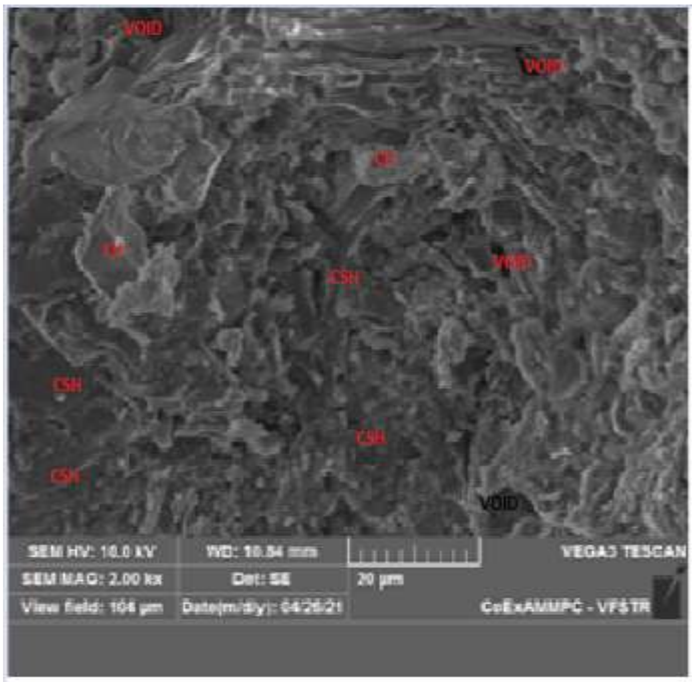

Figure 3(b): SEM image for 0.2%SAP mix (28 days)

3.2 Effect of Recycled aggregate

From the Table 2, the influence of recycled aggregate on compressive strength results at 7, 14 and 28 days can be evaluated. For 0% SAP specimens as RA content in the mix increased, the cube compressive strengths decreased. At the age of 7days, the compressive strength of RA0 specimen is 20.28Mpa. The 7^{th} day strength increased by 9.57, 10.11, 26.63 and 34.91% for RA25, RA50, RA75 and RA100 specimens compared to RA0 respectively. Similarly in the case of 1% SAP, the 7^{th} day compressive strength decreased by 13.19, 13.66, 25.71 and 34.77% respectively for RA25, RA50, RA75 and RA100 compared to RA0 specimens. For 0.2% SAP, on the 7^{th} day compressive strength was decreased from 21.48 to 14.22 Mpa. Similarly in the remaining 0.3, 0.4 and 0.5% of SAP doses, the 7^{th} day compressive strength gradually decreased with an increasing the replacement of natural coarse aggregate with RA. On the 7^{th} day compressive strength values of 0.3, 0.4, and 0.5% RA100 specimens decreased by 34.16, 37.44 and 31.9% respectively compared to RA0.

Concerning the 14^{th} day compressive strength, for 0% SAP, RA0 specimens' compressive strength is 26.92Mpa and the strength decreased to 22.71, 20.51, 19.44 and 16.88 Mpa for RA25, RA50, RA75 and RA100 respectively. Comparing RA0 and RA100, the 14^{th} day compressive strength decreased by 34.05, 29.38, 32.87, 37.03 and 40.34% respectively for 0.2, 0.3, 0.4 and 0.5% SAP doses.

Regarding the performance of RA concrete on the 28th day, the compressive strength of RA25,RA50,RA75 and RA100 specimen with 0% SAP decreased by 12.42, 14.29, 27.80 & 34.89% respectively compared to RA0. The 28th day compressive strength of concrete made of 0.1% SAP decreased from 34 Mpa to 29.51, 28.89, 24.09, 21.82 Mpa with an increase of RA content from 0 to 25, 50, 75 and 100 respectively. However, the compressive strength of RA25, RA50, RA75 and RA100 specimens of 0.2% SAP decreased by 12.38, 14.34, 27.78 & 34.82% respectively compared to RA0 specimens. For 0.3, 0.4 & 0.5% SAP, the strength decrement percentage ranges of RA0 specimens are 12.35 to 36.24%, 12.66 to 37.01% & 12.46 to 36.15% respectively compared to RA25 to RA100. From the above discussion it is observed that, with the increment of RA content in the mixture, the cube compressive strengths decreased by almost 15% for RA25& RA50 specimens when compared to RA0 specimens. However, for RA75 & RA100 specimens, the strength decrements are considerable and are more than 30% compared to RA0 specimens. At 7th day and 14th day also the reduction of compressive strength with RA replacement is noticed but at 28 days strength result it is clear and pronounced. Up to RA50 the strength reduction was marginal but after that the strength reduction was considerable.

Table 2. Compressive strength (MPa) of various concrete mixtures

Sl. No	SAP %	RA-0	RA 25	RA 50	RA 75	RA100	RA 0	RA 25	RA 50	RA 75	RA100	RA 0	RA 25	RA 50	RA 75	RA100
		7 days					**14 days**					**28 days**				
1	0.0	20.28	18.34	18.23	14.88	13.20	26.92	22.71	20.51	19.44	16.88	33.24	29.11	28.49	24.00	21.64
2	0.1	21.08	18.30	18.20	15.66	13.75	24.82	22.72	20.51	19.75	16.37	34.00	29.51	28.89	24.09	21.82
3	0.2	21.48	20.01	17.81	15.51	14.22	24.54	22.70	23.65	19.20	17.33	34.09	29.87	29.20	24.62	22.22
4	0.3	20.20	18.86	19.10	15.28	13.30	25.16	21.77	23.03	18.57	16.89	33.11	29.02	28.09	23.51	21.11
5	0.4	21.13	17.88	18.08	14.82	13.22	25.76	23.07	21.98	18.53	16.22	33.02	28.84	27.82	23.16	20.80
6	0.5	19.25	17.13	16.78	14.33	13.11	24.39	22.75	20.36	18.72	14.55	32.09	28.09	27.51	23.11	20.49

Note: In the nomenclature of the mixture 'RA' represents the recycled aggregate and numerical value indicates the replacement level of recycled aggregate. For example, RA0 indicates the concrete mixture made of 0% replacement of recycled aggregate.

Conclusions

From the present investigation the following conclusions are elicited

- The optimum dosage of SAP to improve the compressive strength of concrete is 0.2%.
- The compressive strength values increased up to 0.2%SAP and after that decreased considerably.
- RAC0, 25, 50, 75 and 100% mixes at 0.2%SAP showed a increment of strength 2.56, 2.61, 2.49, 2.58 and 2.68% when compared with 0.2% SAP concerned mixes. Averagely the strength incitement for RAC mixes with 0.2% SAP is 2.58%. and with 0.1%SAP is 1.25%.
- At 7 and 14 days of age, the effect of SAP percent is not clear but in 28 days the result is clear and pronounced
- For 0.2% SAP mixture, with the increment of RA content the strength decreased by 15% for RA25& RA50 specimens compared to RA0 specimens and for RA75 & RA100 specimens, the strength decrements are considerable and are more than 30%.
- With the provision of SAP for RAC mixes the curing period can be reduced and it is viable for open air curing.

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