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Performance of Self Compacting Concrete Incorporating Coarse Recycled Concrete Aggregates Exposed to Sulphate Attack

Saurav Saini, Ankit Thakur

Abstract: ***The interpretation of the performance of self-compacting concrete made with distinct proportion of coarse recycled concrete aggregate (RCA) (0%, 25%, 50%, 75% and 100%) exposed to sodium sulphate solution (50 gram/litre) under fully immersion condition is studied in this paper. Compressive and tensile strength development/degradation, mass change and length change under sulphate attack was surveyed for all tested units. According to the results it can be conclude that the use of coarse recycled concrete aggregate does not affect the development of strength of concrete with respect to natural material mixtures. It also conclude that for producing of sustainable and green concrete, the quality of used coarse recycled concrete aggregate is an important factor. The differ proportion of coarse recycled concrete aggregate & duration of immersion of concrete in sulphate solution also affect the concrete properties. Reusing recycled combination has twin property benefits: benefiting many tons dismantled concrete worldwide and conserving natural aggregates.***

Keyword: ***Performance Interpretation self-compacting concrete***

I. INTRODUCTION

The objective of this was to evaluate the performance of SCC incorporating coarse recycled concrete aggregates under the actions of sulphate attack. Five types of mixes (with different proportion of coarse RCA 0%, 25%, 50%, 75% and 100%) is exposed to sodium sulphate solution (50 g/L) under fully submerse condition for about 28days and 56days. During this period of corrosion, all the specimens were tested by means of strength in compression and strength in tension, mass change and length change. The comparison were taken out between the natural concrete and concrete with different proportion of coarse RCA.

Concrete is a heterogeneous material consisting of geological aggregates, hydraulic cement-based binder and water. In the last two centuries, due to the introduction and of metal reinforcements, concrete has become one of the most important structural materials. Buildings, dams, transport infrastructures, underground structures for storage and supports for machines are just some of the applications of plain and reinforced concrete. Concrete structures have been Constructed in greatly heterogeneous climatic and environmental contexts. Particularly harsh external conditions can reduce the durability of the structure through several deleterious chemical and physical processes. The consequences of these phenomena can be substantial, both in terms of load-bearing capacity and functionality (loss of stiffness, cracking, spalling). Degradation process can result from chemical reactions due to the penetration of external ions such as chlorides or sulphates or from slow expansive reactions between the components of the concrete as in the case of alkali-silica reaction or alkali-carbonate reactions. All these phenomena are strongly dependent on the porous structure of concrete and on the specific chemical composition of cement and aggregates. While in new structures designed for aggressive environments the chemical degradation can be prevented or at least mitigated by the use of special cements or additives, the safety assessment of structures built several decades ago requires a proper chemo-mechanical modelling of the phenomena. This thesis is focused in particular on the degradation process related to the sulphate attack.

Main Properties of Concrete 1. The mix of concrete should be workable so that it can be consolidated & placed by us without any need of extra workmanship. 2. Concrete in hardened state should met with desired qualities: as examples, should be resistance to thawing & freezing and protective from chemicals. In hardened state, concrete should be low permeable. 3. Economy: Since the quality depends for the most part on the water to bond proportion, the water necessity ought to be limited to diminish the concrete prerequisite (and accordingly decrease its cost). Following steps can be used to lower down the w/c ratio:

- Possible stiffest mix should be used.
- Use most important size combination of aggregates sensible for the duty.
- Optimum quantitative relation of coarse and fine aggregates should be used.

Self-compacting mix is that type of concrete, which have high flow ability so that it can spread in any forms without the actual need of vibration by mechanical means. SCC mix is non-segregating in nature so that it can be placed by its own weight. The SCC mix have importance that it meets all the expected performance requirements like as strength and durability. In SCC mixes, sometimes to reduce the chances of segregation & bleeding, some types of viscosity modifiers & super-plasticizers are added. Since if the SCC mix segregates than it leads to honeycombed structure and will result in loss of strength.

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* Correspondence Author
Saurav Saini*, M. Tech Student, Department of Civil Engineering, National Institute of Technology, Hamirpur – 177005, Himachal Pradesh, India.E-Mail : sukhesingh1110@gmail.com
Ankit Thakur, Assistant Professor, Department of Civil Engineering, Alakh Prakash Goyal Shimla University, mehli, Shimla – 171013, Himachal Pradesh, India.E-mail: ankit.thakur033@gmail.com

So we can conclude that a perfect SCC mix is that mix which does not segregate and has high deformability in fresh state & stability characteristics also good.

Properties of Self Compacting Concrete SCC mix opposes the segregation of concrete & this type of concrete can be get by using fillers of minerals and admixtures of special type. Since in heavy weight buildings, the design of reinforcement is very heavy and spacing between reinforcement is very less so we can-not use mechanical vibrators at that place than there we can use SCC mix because SCC mix is very flow-able in nature and can be passed through heavy reinforced areas and can be fill all the area with avoiding the segregation. So in terms of flow and placements this concrete must be meet special requirements. In SCC mix vibration of concrete by mechanical means does not require since it is selfcompacting mix, so for similar water content or w/c ratio SCC mix have some high strength as compare to mix compacted by mechanical vibrators. Reason behind this is that without vibration the interface of hardened paste and concrete is improved. The speed of placing of concrete is higher in case of SCC mix as compare to natural concrete. Since SCC mixes are segregation resistance so SCC mix can be placed from a height more than 5meters without occurrence of segregation. It can be utilized as part of zones with congested & typical reinforcement, with aggregate as large as 2inches.

Uses of Self-Compacting Concrete Pre-cast concrete sections & bridges can be constructed by using SCC. Akashi-Kaikyo suspension bridge is one of the remarkable project which constructed by using selfcompacting concrete. In this thesis work, the mixing site is located 200meter away from casting site, so SCC mixes were mixed on-situ site & transferred to casting site by using pumping system. So by using SCC mix the construction period of that bridge reduced from 2 year to 2.5 year.

A. Sulphate Attack on Concrete

Sulphate exposure of concrete can be treated as chemical break down process where ions of sulphate attacks on the cement paste components. The responsible compounds for attack of sulphate are water soluble incorporating salts, example alkali earth (magnesium & calcium) & alkali (potassium & sodium) and sulphates that can lead to chemical reaction with concrete components.

B. Reactions that involves in Sulphate Attack on Concrete

Type of sulphate reaction: may be physical & chemical reaction. Due to the sulphate exposure on concrete, the durability of concrete decreases due to alternating the nature of paste of cement and in the concrete mechanical properties. Chemical Process The sulphate ion combines with the hydrated calcium aluminate or hydroxides of calcium of hardened cement paste with available water to form the etrrigites(calcium sulpho-aluminate hydrate).

2CH + C3A.Cs.H18 + 2s + 12H=C3A.H32.3Cs 2CH + C3A.CH.H18+ 3s + 11H=C3A.H32.3Cs

The sulphate ion combines with the hydrated calcium aluminate or hydroxides of calcium of hardened cement paste with available water to form the gypsum(calcium sulphate hydrate).

$$Ca(OH)2 + Na2\,SO4 + 2H2O = 2NaOH + CaSO4.2H2O$$

$$Ca(OH)2 + MgSO4 + 2H2O = Mg(OH)2 + CaSO4.2H2O$$

The occurrence of two forms of chemical reactions depend upon:

- Sulphate ion concentration and source of it.
- Cement paste composition in concrete.

Physical Process of Sulphate Attack

- The difficult physic-chemical procedure of "sulphate assault" are associated just like the subsequent harm.
- Physical sulphate assault, regularly prove by sprout (the nearness of sodium sulphates $Na2\,SO4$or potentially $Na2\,SO4.10H2O$) at uncovered solid surfaces.
- It isn't just a restorative issue, yet it is the unmistakable showing of conceivable substance and micro-structural issues inside the solid lattice.

Preventive measures of Sulphate Attack on Concrete

The following points can help to prevent sulphate assault:

1. The nature of cement, particularly a low porousness, is the best security against sulphate assault.
    - Solid thickness should be adequate.
    - Bond content should be high.
    - Low w/c proportion.
    - Curing & compaction should be proper.
2. The utilization of sulphate opposing bonds give extra security against sulphate assault.

Table 1 Types of sulphate attack

Exposure	Water soluble sulphate ion concentration present in soil	Water soluble sulphate ion concentration in water ppm
Mild	< 0.10	< 150
Medium	0.10 to 0.20	150 to 1500
Severe	0.20 to 02	1500 to 10000
Very severe	> 02	> 10000

II. MATERIAL PROPERTIES, MIX DESIGN AND EXPERIMENTAL SETUP

A.Material Used and Their Properties

1) Cement

Ordinary Portland Cement of Grade 43 & Specific Gravity 3.10. OPC 43 will confirm to IS: 8112-1989 and the designed compressive strength of 28 days will be atleast 43 MPa. The early strength of OPC of grade 43 is less than that of 53 grade but with the time passes it attains the equal ultimate strength as similar of 53 grade. The initial setting time of 43 grade OPC is slower than that of 53 grade OPC that is the rate of hydration process for 43 grade OPC is slow so the release of heat of hydration is moderate and it will result in less micro cracks and easily controlled out by proper curing. Where grade of concrete is up to M-30 in RCC works, 43 grade OPC is preferred.

2) Fly Ash

- Class F fly ash.
- Colour is Grey obtained from Thermal Power Station, Panipat (Haryana).
- Specific Gravity is 2.13.

Class F fly ash is generated by burning of the harder and older anthracite & bituminous.

The nature of fly ash is pozzolonic & the lime content is less than 7%. When we use class F fly ash as a substitude of Portland cement, we should keft mind some precautions. The setting time may be slightly increased and the early strength in compression of concrete may be slightly decreased. Fly ash also have lower bulk specific gravity so we have to modified the fine aggregate fraction in concrete. Fly ash should not be used in hydraulic conditions because fly ash has high calcium content. Many experiments shown that fly ash can be used up to 30% by weight of Portland cement and above that it may cause decrement in different properties of concrete.

3) Superplaticizer

- Poly-carboxylic ether based high range water reducer.
- Sika viscocrete 1062NS is used.
- Colour is Brown.
- Solid content is 40%.
- Relative density at 25°C is 1.07 kg per lt.

Super plasticizers means high range water reducers, are the chemical admixtures which are used for good dispersed particle suspension. By the use of super plasticizer, we can avoid the segregation and can upgrade the flow properties of concrete. The use of super plasticizer reduced the water to cement ratio and corresponding not affect the workability of concrete. Self-compacting concrete and high performance concrete can be produced by using super plasticizer. The use of super plasticizer also increased the hardened properties of concrete in very good manner. As the water to cement ratio lowers down, strength increases. The Poly-carboxylic ether based high range water reducers are kind of new generation super plasticizer. With a low doses of this, it may reduce water to cement ratio up to 40%. The using Poly-carboxylic ether based high range water reducer should be compatible with the cement and all aggregates used in concrete.

Fig. 1 Natural coarse aggregate

Aggregates

Table 2 Properties of aggregates

Type	Max Size (Mm)	Min Size (Mm)	Specific Gravity	Water Absorption	Fineness Modulus
Natural Coarse Aggregate	20	4.75	2.76	0.68%	6.766
Coarse RCA	20	4.75	2.64	2.8%	6.90
Natural Fine Aggregate	4.75	0.075	2.56	1.6%	2.549

Three type of aggregates are used for design of concrete-

Natural Coarse Aggregate – Natural coarse aggregate are used of size from 4.75mm to 20mm. The specific gravity of natural coarse aggregate were 2.76. All the natural coarse aggregate should be free from dust and any other organic content. The water absorption of natural coarse aggregate were 0.68%. The proportion of natural coarse aggregate is done in a way that we get fineness modulus of 6.766.

Coarse Recycled Concrete Aggregate – The size of coarse RCA used id from 4.75mm to 20mm and in such proportion so that fineness modulus were 6.90. The water absorption of used coarse RCA were 2.8%. The specific gravity of used coarse RCA were 2.64. The coarse RCA is achieved by crushing the wasted from the laboratory. We noticed that a layer of mortar is attached to that crushing material so we remove that mortar by wear and tear process. Since presence of excess mortar can absorb the lot of water which result in less workability of fresh concrete. The grains of coarse RCA are irregular, most of them with angular shape and with cracked surface. Some of them are rough and porous. So these grain properties significantly alter the workability of concrete in fresh state and as well as the permeability of hardened concrete. So to overcome from these problems, the properties of concrete used for recycling is good and the level of recycling also good and adding to this type of applied crusher and proper sieving also maintained.

Fig. 1(a). Coarse RCA Fig. 1 (b). Natural Fine Aggregate

Table 3 Sieve analysis of natural coarse aggregates

S.No.	Size of Sieve (in mm)	Weight Retained (in gram)	Cumulative Weight Retained	Cumulative
1	20	0	0	0
2	10	2300	2300	76.6
3	4.75	700	3000	100
4	2.36	0	3000	100
5	1.18	0	3000	100
6	0.6	0	3000	100
7	0.3	0	3000	100
8	0.15	0	3000	100
		Sum	=	676.6

Total weight of concrete taken= 3kg
So, fineness modulus of 20mm natural coarse aggregate= 676.6/100=6.766

Natural Fine Aggregate - Natural fine aggregate are used of size from 0.075mm to 4.75mm. The specific gravity of natural fine aggregate were 2.54. All the natural fine aggregate should be free from dust and any other organic content. The water absorption of natural fine aggregate were 1.6%. The proportion of natural fine aggregate is done (1) in a way that we get fineness modulus of 2.54. The aggregate of size less than 0.075mm are known as silt. So natural fine aggregate should be free from the silt because if the silt is present in the natural fine aggregate than the water requirement increases thus workability gets affected and strength also affected.

Table 4 Sieve analysis of natural fine aggregate

S.No.	Size of Sieve (in mm)	Weight Retained (in gram)	% Retained	Cumulative % Retained
1	4.75	0	0	0
2	2.36	75	7.5	7.5
3	1.18	180	18	25.5
4	0.6	220	22	47.5
5	0.3	272	27.2	74.7
6	0.15	250	25	99.7
			Sum =	254.69

Total weight of natural fine aggregate taken= 1000gram
So, fineness modulus of natural fine aggregate= 2.549.

Concluding Remarks – Primarily aggregate act as inert filler, but secondary effect on various concrete & mortar properties. So proper awareness should be made while using the aggregate in any design so that it should result in economical & high performance concrete

Table 5 Sieve analysis of coarse RCA

S.No.	Size of Sieve (in mm)	Weight Retained (in gram)	Cumulative Weight Retained (in gram)	Cumulative % Retained
1	20	0	0	0
2	10	2700	2700	90
3	4.75	300	3000	100
		Sum	=	190

Total weight of coarse RCA taken= 3kg. So, fineness modulus of 20mm coarse RCA= (190+500)/100=6.90

B. Mix design

By using Nan Su method, we design a mix M30 for per cubic metre of concrete. Several changes were made through trials in the design to obtain the good properties of self- compacting concrete. By using trail mixes we adopt proper value of water content and proper dosage of super-plasticizer so that fresh concrete is highly workable and does not lead to segregation.

Mix D0 –

D0 means 0% coarse RCA is used at place of natural coarse aggregate. So mix design for D0 mix –

Table 6 Mix design of D0

Cement	Fly Ash (30% by wt. of cement)	Natural Coarse Aggregate	Fine Aggregate	Super-Plasticizer (1% by wt. Of binder)	Water (water/cement ratio 0.45)
415 kg	120 k.g.	760 k.g.	850 k.g.	5.35 k.g.	190 lt.

Mix D25

D25 means 25% coarse RCA is used by weight of natural coarse aggregates. So mix design for D25 mix –

Table 7 Mix design of D25

Cement	Fly Ash (30% by wt Of cement)	Natural Coarse Aggregate	Fine Aggregate	Super-Plasticizer (1% by wt. Of binder)	Coarse RCA	Water (water/cement ratio 0.46)
415 k.g.	120 k.g.	570 k.g.	850 k.g.	5.35 k.g.	190 k.g.	191 lt.

Mix D75

D75 means 75% coarse RCA is used by weight of natural coarse aggregates. So mix design for D75 mix

Table 9 Mix design of D75

Ce me Nt	Fly Ash (30% By Wt. Of Cemen T)	Natu ral Coar se Aggr ega Te	Fine Aggre ga Te	Super-Plasticiz Er (1% By Wt. Of Binder)	Coar Se Rca	Water(Water/Cem Ent Ratio 0.52)
415 K.G.	120 K.G.	0 K.G.	850 K.G.	5.35 K.G.	760 K.G.	215.8 Lt.

D100 mix

D100 means 100% coarse RCA is used by weight of natural coarse aggregates. So mix design for D100 mix

Table 10 Mix design of D100

Ceme Nt	Fly Ash (30% By Wt. Of Cemen T)	Natural Coarse Aggrega Te	Fine Aggrega Te	Super-Plasticiz Er (1% By Wt. Of Binder)	Coar Se Rca	Water(Water/Cem Ent Ratio 0.52)
415 k.g.	120 k.g.	0 k.g.	850 k.g.	5.35 k.g.	760 k.g.	215.8 lt.

Note- Mass change and length does not require to caste different specimens since these results can be computed from the specimens that were casted for compressive and split tensile test.

So, volume of 1 cube= .150×.150×.150=0.003375 cubic meter & volume of 1 cylinder = 3.14×.050×.050×.200=.00157 cubic meter

Total Volume of Concrete in Cubic meter=45×.003375+45 = **0.222525**

Estimation of Quantity of Concrete

Description	Compressivestrength test	Split tensile test	Mass change	Length change
Specimen size	Cube	Cylinder	Cube	Cylinder
Number of concrete mixes	5 (D0,D25,D50,D 75& D100)	5 (D0,D25,D50,D 75& D100)	5 (D0,D25,D50,D 75& D100)	5 (D0,D25,D50,D 75& D100)
Days of testing	28 days water curing. Than 28 days sulphate attack. And 56 days of sulphate attack.	28 days water curing. Than 28 days sulphate attack. And 56 days of sulphate attack.	28 days water curing. Than 28 days sulphate attack. And 56 days of sulphate attack.	28 days water curing. Than 28 days sulphate attack. And 56 days of sulphate attack.
Total number of specimens	45	45	45	45

C. Experimental Work

The following steps are used in this experimental work-

Type of test specimens

Two types of specimens were used in these investigation namely the cubic and cylindrical. The size of used cubes were of size 150×150×150mm and size of used cylinder were 100mm diameter and 200mm length.

Preparation of moulds

Cubic and cylindrical moulds were cleaned and oiled so that after setting out of concrete they can be easily demoulded. After performing the tests for flow characteristics, the moulds were filled with the concrete. There is no need of compaction because that concrete is self-compacting concrete.

Preparation of concrete

The samples were prepared by mixing of upper mentioned materials in appropriate proportion. Process is represented in flow chart below – (in fig. 3.1)

MixingFive different type of samples were prepared by changing the weight percentages of natural coarse aggregate with coarse RCA (0%, 25%, 50%, 75% and 100%). These content were mixed fully by a mechanical mixer to get a homogenous mixture.

Curing of samples

After 1day of filling the moulds i.e. after setting time, all the moulds were demoulded and imposed to water curing for next 28 days

D. Hardened Properties of Concrete

1) Compressive Strength

In order to find the strength in compression of all samples by UTM machine. The test was carried out at temperature of room and the complete scale range load of 50 KN. Minimum three specimens made from the same concrete were required for computation of strength. First of all we have to clean the bearing surface of compressive testing machine and the specimen axis should adjusted with the centre of thrust of plate. The load vs. displacement signals is get from the computer integrated machine directly when samples were

This computer operated machine provides the Load vs. displacement signals straightly when the samples were exposed to tests.

Strength in compression = P/AWhere, A= Bearing cube surface area, & P = Failure load.

Fig. 2 Compressive strength testing machine

Fig. 3 Cubical Sample for Compressive strength test

Fig. 4 Cylindrical Samples for Split tensile test

Length Change Calcium aluminates generally affected by sulphates in cement. Cement hydration can get negative effect due to sulphate ion and it may result in decrement of cement strength. In this study, the effect of sodium sulphate solution on the concrete is investigated out. If we add super plasticizer in the concrete in proper amount than it increases the positive properties of concrete and made the concrete more effective, prevent highly alkali- aggregates reactions that result in less length change of concrete.

2) Mass change

This method is to determine the chemical resistance of concrete by immersing the test samples in 5% sodium sulphate solution and by comparing the changes in the mass with the normal curing samples.

For this study, sulphate attack resistance has been measured by mass change ratio as shown below

Mass change ratio (in %) = $(W1-W2 /W2)\times 100$

Where, $W1$ is mass of sample immersed in solution at the measuring age and $W2$ is mass of concrete before immersion in test solution

Split Tensile Strength Test

In this procedure, compressive force is applied diametrically along the cylindrical length of the sample. Stresses in tension were induced on the plane which have the applied load. Due to the development of tensile stresses, tensile failure occurs, not the compressive failure. Splitting tensile strength can be obtained correspond to the ultimate load divided by relevant geometrical factors.

III. RESULTS AND DISCUSSION

A.Compressive Strength

The strength in compression of cubic samples were measured as per standard practice. Three samples were tested for each composition and the average of three values is taken out as the result

Table 12 Compressive strength of all samples

S.NO.	MIX	COMPRESSIVE STRENGTH (MPa)		
		After 28 days of water curing	After 28 days of sulphate attack	After 56 days of sulphate attack
1	D0	32.6	1.94	31.3
2	D25	31.45	0.5	29.59
3	D50	28.68	7.82	26.98
4	D75	26.4	5.34	24.33
5	D100	23.35	1.71	20.2

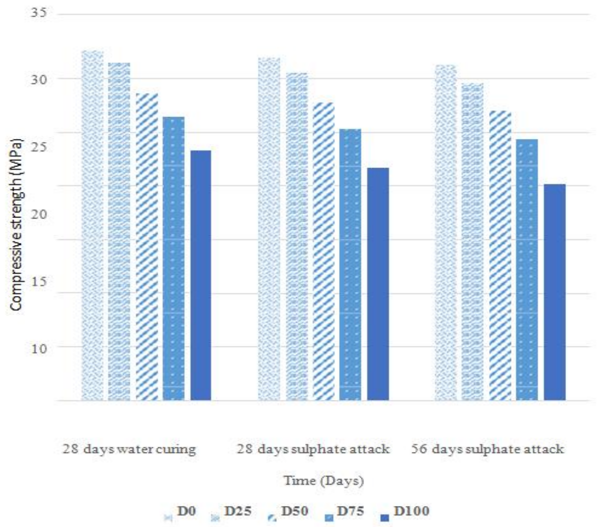
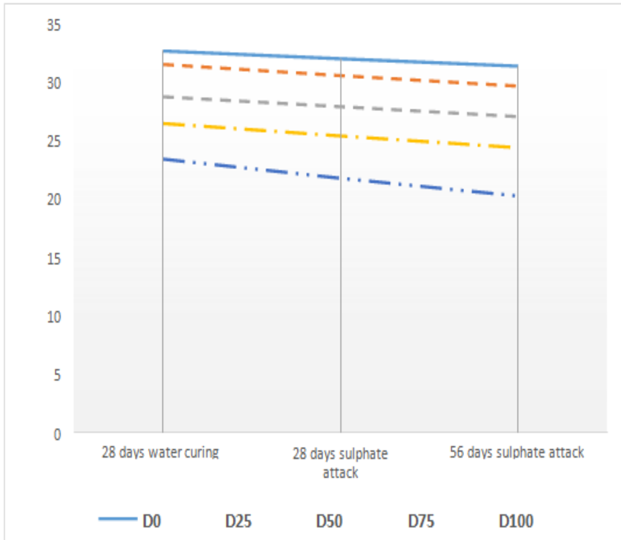


Fig. 5 Compressive strength variation by bar chart

As shown in above bar chart, first of all after 28 days curing by water, the mix D0 and D25 showed compressive strength more than 30MPa. As we design concrete for strength for M30 so mix D0 and mix D25 showed appropriate strength. But as we increase the proportion of coarse recycled concrete aggregate above than 25% by weight of natural coarse aggregate, the strength in compression of that concrete gone below the 30MPa. So for appropriate compressive strength we can use coarse recycled concrete aggregate up to certain proportion and this value can range up to maximum value of 40% by weight of natural coarse aggregates. This bar chart also shown the effect of next 28 days and 56 days sulphate attack on concrete. It shows that as the duration of sulphate attack increases, more will be the loss in strength in compression of concrete. Bar chart also shown that as the % of coarse recycled concrete aggregate increases, the decrease in compressive strength increases.]



As shown in the line chart, the compressive strength of mix D0 is always maximum after 28 days of water curing, than further 28 days and 56 days of sulphate exposure. This line chart shown that as the percentage of coarse recycled concrete aggregates increases, the strength decrement is more than that of mix D0.

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We noticed in line chart that as we move from mix D0 to mix D100, the slope of lines also increases in that manner, respectively. Since the slope is negative, and slope increases from mix D0 to D100, so maximum decrease of compressive strength is in mix D100. So we conclude that mix D100 is more severe to sulphate attack and this conclusion lead to point that as the percentage of coarse recycled concrete aggregate increases, more will be the loss in compressive strength due to sulphate attack. If we want to use higher percentage of coarse recycled concrete aggregate, than proper care and precautions should be take care. The recycled concrete aggregate should be of proper quality and admixtures used should be compatible with the cement

B. Length Change

Miller and Manson proposed that 0.2% of expansion as the limit for sulphate resistance of concrete. As in our results of cylinders, the change in length is not too much in all type of mixes and in all type of exposure conditions. The length change is negligible and thus, concrete expansion may be attributed to the normal swelling of concrete. The normal swelling of concrete is due to the excess free water in the concrete mixture due to which concrete bleed out. After plastic settling has finished, the extra water is drawn back in to the hardened cement paste by weak capillary suction. The re-absorption is the reason for normal swelling of concrete, due to which length may be changed.

C. Mass Change

Polviska reported that the loss of mass is the best indicator to assess the degree of deterioration compared to change in length

Table 13 Mass change for all the mixes

S.No.	Mix	Weight after 28 days of water curing	Weight loss after 28 days of sulphate exposure	Weight loss after 56 days of sulphate exposure
1	D0	7.785 kg	18 gram	29 gram
2	D25	7.697 kg	27 gram	62 gram
3	D50	7.598 kg	35 gram	80 gram
4	D75	7.520 kg	43 gram	98 gram
5	D100	7.470 kg	53 gram	112 gram

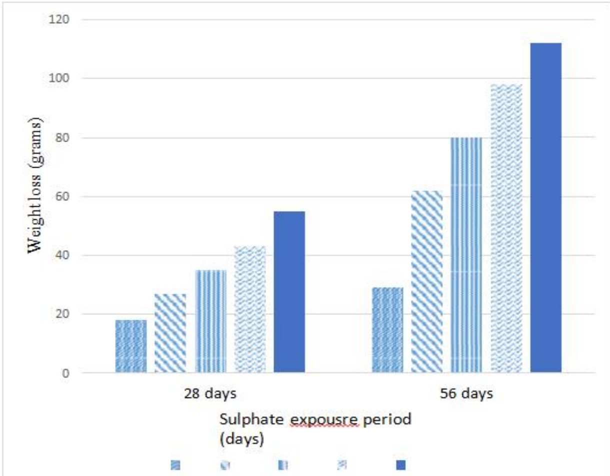

Fig. 7 Weight loss variation of all specimens by bar chart

The mass change or weight change of all specimens with different replacements of coarse recycled concrete aggregate directed to 5% sodium sulphate solution for 28 days and 56 days after water curing are represented in bar chart. The changing trend in mass of all different specimens are similar as that of coarse recycled concrete aggregate replacements. From the help of bar chart or readings, we can clearly states that the mass change of all samples are simply leveraged by the inclusion of coarse recycled concrete aggregate. At the low level of coarse recycled concrete aggregate replacement, the mass change is minimum but as we move toward high level of coarse recycled concrete aggregate replacement, the change in mass of the specimens also increases. From the above bar chart it is also noticed that if the exposure period of sulphate attack increases than mass change also increase. Same type of sample have different value of mass loss for different exposure period to sulphate attack and trend follows by all type of different samples. The mass loss for all samples are greater for 56 days of sulphate exposure than that of 28 days of sulphate exposure. So the minimum weight loss is for mix D0 under 28 days of sulphate attack and maximum weight loss is for mix D100 under 56 days of sulphate attack. So weight loss is function of both one is exposure period to sulphate solution and second is proportion of coarse recycled concrete aggregate by weight of natural coarse aggregate.

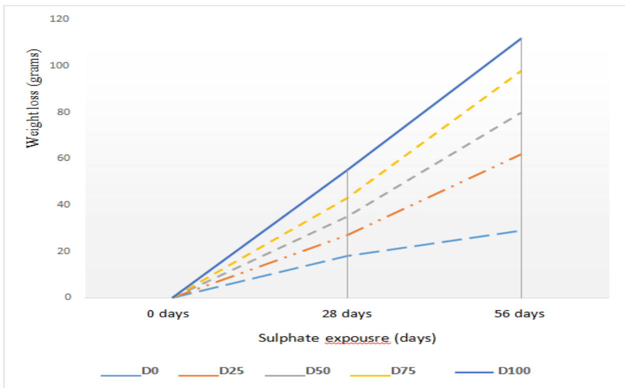

Fig. 8 Weight loss variation of all specimens by bar chart

From the above line chart, it is concluded that the rate of mass loss or weight loss is increases as the % of coarse RCA increases. This behaviour of weight loss is due to the reason that the initial sample is assumed at an un-saturated state leads to water inhibition till reach to max saturation. Diversely the expansive reaction outputs formed during the erosion reaction can fill the pore structure. The increase in weight loss can be understand by the fact that, during the process of coarse recycled concrete aggregate, it has high porosity of adhere mortar & micro cracks are also present. There are also some positive effect of using coarse recycled concrete aggregate that they absorb water and result in water to cement ration will result in increase of compressive strength but will also result in less workability. If the reaction due to sulphate exposure expands continuously than cracks will generated and this will result in more weight loss of concrete and at last leads to surface spalling of concrete. The cracks are develop when products due to reaction of sulphate expands continuously and the stress due to expansion is larger than that of tensile strength of concrete. So if we want less weight loss than the coarse recycled concrete aggregate used should be free from the cracks and the adhere mortar should be minimum as much possible. The quality of demolished concrete from where coarse recycled concrete aggregate produced should be good enough such that their properties can be comparable as that of natural coarse aggregate.

D.Split Tensile Test

The strength in tension of concrete is one of the important & basic property. The strength in tension of concrete can be determine by the splitting tensile test on cylindrical samples of concrete. As we know that concrete is brittle in nature so it is very weak in tension so concrete can not resist the direct tension. When the concrete is subjected to tensile forces, cracks develops. Thus, the determination of strength in tension of concrete is important so that we can determine the load at which cracks may be develop in concrete. Atleast three number of specimens are required for every type of sample to determine the tensile strength of concrete and average of those three samples are taken as value of strength in tension of concrete.In general, the splitting strength in tension of concrete varies between 1/8 to 1/12 of the strength in compression of concrete. But it is not the relationship among strength in tension & strength in compression always that if we increase the strength in compression of concrete by any mean than there also should be increment in strength in tension of concrete. The above range is given only to anticipate the strength in tension of concrete from known strength in compression of concrete.

Table 14 Tensile strength of all samples

S.NO.	MIX	TENSILE STRENGTH (MPa)		
		After 28 days of water curing	After 28 days of sulphate attack	After 56 days of sulphate attack
1	D0	4.8	4.71	4.62
2	D25	4.46	4.33	4.2
3	D50	4.18	4.02	3.85
4	D75	3.8	3.56	3.41
5	D100	3.24	3.01	2.78

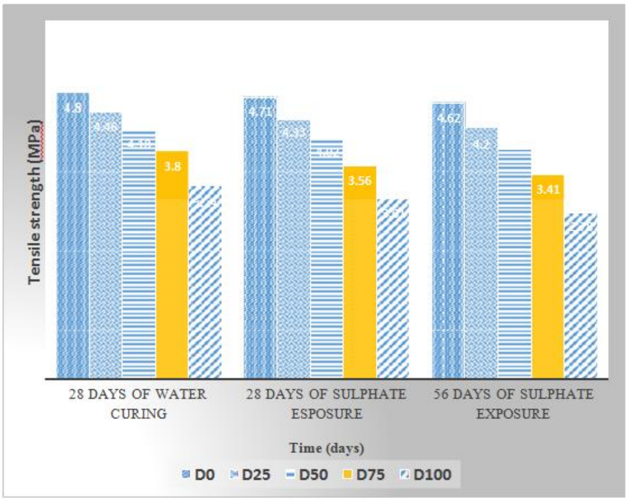

Fig. 9 Tensile strength variation by bar chart

As shown in above bar chart, first of all after 28 days of water curing, the mix D0 and D25 showed tensile strength more than any other mixes. So mix D0 and mix D25 showed appropriate strength than any other mix after water curing. So as we increase the proportion of coarse recycled concrete aggregate above than 25% by weight of natural coarse aggregate, the tensile strength of that concrete decreases fastly. So for appropriate tensile strength we can use coarse recycled concrete aggregate up to certain proportion and this value can range up to maximum value of 40% by weight of natural coarse aggregates. This bar chart also shown the effect of next 28 days and 56 days sulphate attack on concrete. It shows that as the duration of sulphate attack increases, more will be the loss in tensile strength of concrete. Bar chart also shown that as the % of coarse recycled concrete aggregate increases, the decrease in tensile strength increases.

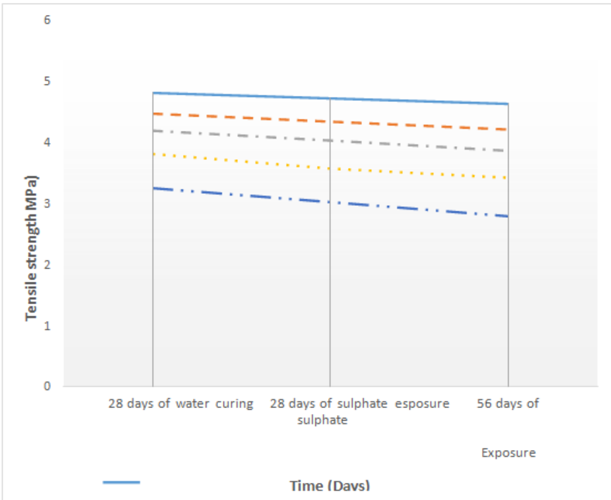

Fig. 10 Tensile strength variation by line diagram

As shown in the line chart, the tensile strength of mix D0 is always maximum after 28 days of water curing, than further 28 days and 56 days of sulphate exposure. This line chart shown that as the percentage of coarse recycled concrete aggregates increases, the tensile strength decrement is more than that of mix D0.

We noticed in line chart that as we move from mix D0 to mix D100, the slope of lines also increases in that manner, respectively. Since the slope is negative, and slope increases from mix D0 to D100, so maximum decrease of compressive strength is in mix D100. So we conclude that mix D100 is more severe to sulphate attack and this conclusion lead to point that as the percentage of coarse recycled concrete aggregate increases, more will be the loss in compressive strength due to sulphate attack.

IV. CONCLUSIONS

On the basis of this study, subsequent conclusions are drawn: Self-compacting concrete gives better finishing in comparison to other normal concrete without need of any external compaction.

The incorporation of coarse recycled concrete aggregate shows obvious effect on the resistance of concrete under fully submerged sulphate exposure condition. The effect would be differ depending upon the positive effect that high water absorption of coarse RCA makes the concrete denser but the negative effect is that higher porosity and cracks in coarse RCA.

Due to the sulphate attack, reduction in compressive strength and tensile strength arises and after sulphate attack reduction in strength of coarse RCA mixed concrete reduced up to 7% whereas for normal mixed concrete reduced up to 2.5%.

The strength of mix D100 at 56days of sulphate exposure was most affected so as the sulphate exposure time on concrete increases, reduction in concrete strength also increases and as the quantity of coarse recycled concrete aggregates increases, reduction in strength also increases.

As we design the concrete for strength 30MPa. Up to 40% replacement of natural coarse aggregate by coarse recycled concrete aggregate, we achieved the concrete of strength more than 30MPa. So 40% coarse RCA replacement is the upper limit that can we use at the place of natural coarse aggregate.

As deterioration is measured with help of mass change, and maximum mass change is for concrete mix D100 at 56days of sulphate exposure so we can conclude that as the quantity of coarse recycled concrete aggregate increases, deterioration also increases and as the sulphate exposure period on concrete increases, deterioration also increases.

Reusing recycled concrete aggregate has dual benefits: use hundreds of ton demolished concrete that preserves the land-fills and preserve the natural aggregates.

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AUTHORS PROFILE

Saurav Saini, M.Tech Student, Department of Civil Engineering, National Institute of Technology, Hamirpur – 177005, Himachal Pradesh, India

Ankit Thakur, Assistant Professor, Department of Civil Engineering, Alakh Prakash Goyal Shimla University, mehli, Shimla – 171013, Himachal Pradesh, India

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