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Experimental Study on Mechanical & Durability Properties of Recycled Coarse Aggregate Concrete

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ABSTRACT : The cost of construction substances is presently so excessive that most effective governments, company corporations and wealthy individuals can manage to pay for to do meaningful structures. For this purpose there is random demolition of homes round the arena. Due to this 33% of stable waste is being generated that's developing a number of chaos due to land for disposal. Only 3% out of 33% waste is being recycled and utilized in pavement blocks, kerbs, base path materials etc. The barriers in effective usage of recycled concrete are lack of guide strains, specialists great vision, loss of codes for the use of incorporating recycled aggregates and poor photograph concerning the pleasant of recycled substances. From the past studies it can be concluded that there's a reduction in 28days compressive strength by 20%. Hence from past research it is able to be conclude that recycled aggregate concrete may be made use in ordinary production.

The difficulty of recycled aggregates in non-structural structures and regular structures dos not remedy the problem of lowering land for its disposal and heavy finances for structures. To use recycled aggregates effectively we have to recognize all its uses and programs increasing the studies to high energy concrete and checking the sturdiness. Thus our motto in the studies is to find the usage of recycled aggregate concrete high excessive strength concrete. The concrete grade considered in this take a look at is M60. The substitute ratios considered are 0%, 10%, 20%, 30% & 40%. Compressive strength, tensile strength & flexural strength are have a look at to recognize the energy for distinct alternative ranges of recycled aggregates. From those research it could be said that the nominal substitute degree is 30% and for this alternative level the study tests acid attack resistance, sulphate & chloride attack resistance and water absorption check is carried out and the compressive energy is checked after the durability take a look at.

KEYWORDS: Demolished recycled aggregates, Compressive Strength, Split tensile Strength, Flexural strength, durability.

I. INTRODUCTION

Concrete is one of the most widely used construction material causing a high demand for it. As a result of this, there is an increase in the demand for its constituents like the coarse aggregates, sand, cement and water. This increase in demand is causing extensive quarrying of natural aggregates as it is required as coarse aggregates in concrete production and also it forms the major constituent by mass in concrete.

The aim of any sustainable construction is to decrease the impact on environment of any construction over its lifetime. Concrete is the main material used in construction all over the world. Due to increase in Construction and Demolition activities worldwide, the concrete wastes generated due to demolition also increases. But this waste is not used for any purpose which is totally loss in the economy of the country because natural resources are depleting at a quick pace. Further the generated concrete wastes pose serious disposal problems as the municipalities are not able to find the best solution for it without affecting the environment. We know that the most common practice all over the world in case of most of the materials (paper, plastic, rubber, wood, concrete, etc.) is recycling to save the natural resources and environment. Concrete is such an expensive and energy consuming material but it is shocking that

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concrete waste is seldom used by recycling the concrete as a recycled concrete aggregate (RCA) to use for the construction purposes. Instead it is just disposed of in landfills.

The main problem involved in using demolished concrete as aggregate is related to achieving good workability. There has already been several developments in this field of improving the performance of concrete and also to overcome problems related to workability in different ways and to continue the improvement to conserve energy, raw materials, development of high strength concrete, prestressed concrete, high early strength, and low possible water/cement ratio while maintaining high workability, to improve mechanical and structural properties of fresh and hardened concrete so as to make structural concrete as economical.

II. LITERATURE REVIEW

1. **M C Limbachiya, et al**, in this investigation the authors included samples from different sources for the study and also have relevant information regarding the original concrete strength. RCA samples were produced in single size fraction (20 - 5mm) using commercial plant for the production of crushed-rock aggregate, comprising primary jaw and secondary cone crushers and screens.
2. **Ismail Abdul Rahman et al**: The effect of size of the recycled aggregates on the strength and workability of the concrete is discussed in this paper. The aggregate properties are analyzed according to BS 882:1992. From the aggregate testing properties the authors conclude that, RA are flakier and more elongated than the corresponding NA.
3. **Irotak a K A WA NO Public Works Research Institute, JAPAN**: This paper summarizes the JIS Technical Report, TR A 0006 "Recycled Concrete Using Recycled Aggregate" published in 2000. The JIS Civil Engineering Committee made a recommendation in 1998 to establish new JIS standards to encourage the use of recycled materials in the construction industry.
4. **MirjanaMaleševet al**: A comparative analysis of the experimental results of the properties of fresh and hardened concrete with different replacement ratios of natural with recycled coarse aggregate is presented in the paper. Three concrete types were tested within the research program. The type and quantity of coarse aggregate: - (R0), control mixture, - (R50), - (R100) and recycled concrete aggregate grain sizes were 4/8, 8/16 and 16/31.5 mm.
5. **SnezanaMarinkovic et al**: In this workshop the authors have presented the various production technologies and some guidelines on the mix design for RCA Production technologies are of two types: Traditional: they can be either stationary or mobile recycling plants but they produce lower quality of RCA and Advanced: they are developed in japan and are of 3 types like heating and rubbing method, eccentric shaft rotor method and straight forward mechanical grinding method.
6. **Parekh D. N.et al**: The authors have compiled a review paper on the use of RAC and have concluded the following: The authors say that the recent research by the Fredonia group has established that the global demand for construction aggregates may exceed 26 billion tones by 2011.
7. **Bilal RiazChughtai**: The effects of size of RA on compressive strength were discussed in this paper. In this research work the recycled coarse aggregates used were Road bed discarded near shell pump Nawababad. Concrete mixes were made with different % of RA content.

III. EXPERIMENTAL INVESTIGATION

With tremendous advancements in the field of construction, it has become a necessity to maintain sustainability in construction. Most of the governments across the world have made it compulsory nowadays to assess the impact on the environment of any construction. It is very essential that any construction does not have any negative impact on the environment. Hence it becomes our responsibility as civil engineers to not only ensure that it is safe and satisfies all the required design criteria but also has no negative effect on environment. One of the best ways to do so would be to use alternative building materials in the place of the conventional materials. This has 2 advantages, one it reduces the depletion of natural aggregates and the other, and it seems to be the most suitable solution for getting rid of demolition wastes.

With increase in urbanization, land availability is continuously reducing and hence dumping of wastes in landfills is becoming increasingly difficult. Hence some alternative has to be found to effectively manage the demolished wastes generated. Further with increased development in standard of living and urbanization, the demand for new and better infrastructure increases making way for demolition of old buildings to be replaced by new ones. Further natural and man caused disasters cause demolition of buildings.

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MATERIALS:

The materials used in present investigation include;

1. Cement-Ordinary Portland Cement (OPC).
2. Fine aggregates.
3. Coarse aggregates.
4. Demolished recycled aggregates.
5. Super plasticizers.

CEMENT:

Ordinary Portland cement of 53 grades was selected for the experimental investigation. The compressive strength characteristics of cement were tested as per IS: 4031-1988 and IS: 12269-1987(9). The cement used in present study was Zuari cement. The experiments such as standard consistency, initial setting time, final setting time and specific gravity of cement are conducted on ordinary Portland cement.

TABLE 1. PHYSICAL PROPERTIES OF OPC

S.No	Characteristic of cement	Value	Code specifications (IS 4031-1988)
1	Fineness of cement	94.76%	-
2	Normal consistency	33%	Not specified
3	Initial setting Time	40 minutes	>30
4	Final setting time	350 minutes	<600
5	Specific gravity	3.14	-

AGGREGATE: It should be passed through IS Sieve. As fine aggregate (F.A) natural sand from river is used conforming to IS383-1970. Which comes under zone II. As a coarse aggregate hard granite chips passing 20mm down where used conforming to IS383-1970. Various tests such as specific gravity water absorption and sieve analysis have been conducted on (F.A) and (C.A) to know the good quality and grading.

TABLE 2. PROPERTIES OF FINE AGGREGATES

S.no	Properties	Results
1.	Specific gravity	2.583
2.	Bulking of sand	4
3.	particle size variation	0.15 to 4.75
4	Water absorption for sand	1
5	Bulk Density of Sand	1460
6.	Fineness modulus of sand	2.8

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TABLE 3.COARSE AGGREGATE PROPERTIES

S.No	Properties	Unit	Results
1.	Specific gravity	-	2.68
2.	Particle size variation	mm	6.35 to 6.4 to 20mm
3	Fineness Modulus	-	6.26
4	Water Absorption	%	0.5
5	Bulk Density	kg/m ³	1469.8
6	Elongation index	%	20.49
7	Flakiness index	%	13.19

DEMOLISHED RECYCLED AGGREGATES: The concrete aggregate that contains 95% of crushed concrete is called recycled concrete aggregates. The construction and demolition waste in its original state consists of wood, gypsum, plastics and many contaminating materials, that have to be removed because of its usage in concrete manufacture.

SUPER PLASTICIZERS: Super plasticizers, also known as high range water reducers, are additives used in making high strength concrete. Plasticizers are chemical compounds that enable the production of concrete with ca. 15% less water content. Super plasticizers allow reduction in water content y 30% or more.

IV .RESULTS AND ANALYSIS

TABLE 4.COMPRESSIVE STRENGTH COMPARISION FOR ALL PROPORTIONS OF RECYCLED AGGREGATE CONCRETE

% replacement	3 days N/mm ²	7 days N/mm ²	14days N/mm ²	28 days N/mm ²
0%	40.58	49.24	50.88	68.2
10%	40.08	49.09	50.32	68
20%	41.88	51.89	54.32	69.50
30%	37.56	48.56	49.03	66.12
40%	35.08	43.21	45.28	57.6

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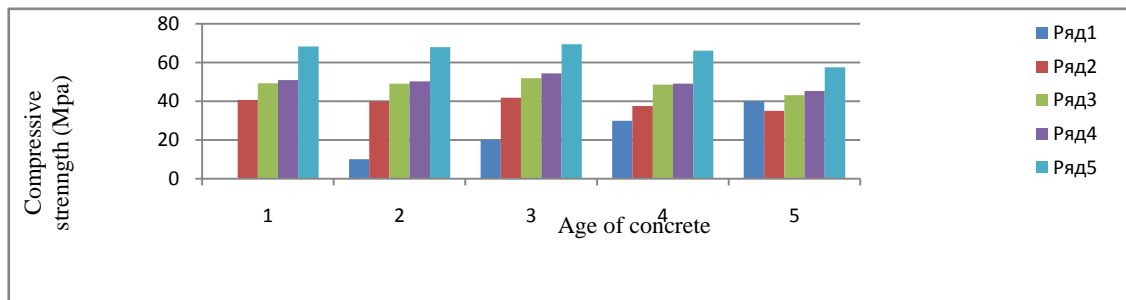


Figure 1: Consolidated graph for compressive strength on concrete with age

SPLIT TENSILE TEST RESULTS:

The indirect tensile strength indicates a decreasing trend of tensile strength when the percentage of recycled aggregate is increased. Table below shows the average tensile strength recorded during the test.

TABLE 5. SPLIT TENSILE STRENGTH RESULTS OF CONCRETE

S.no	Percentage replacement	7 days Split tensile strength	28 days Split tensile strength
1	0	3.02	5.63
2	10	2.12	4.25
3	20	3.21	5.85
4	30	2.52	4.04
5	40	2.11	3.14

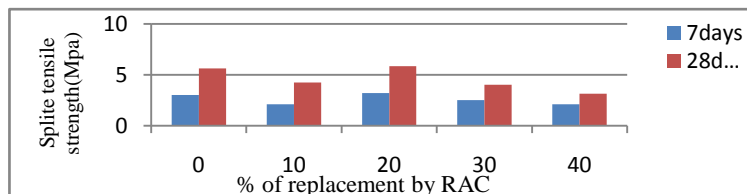


Figure 2: consolidates graph for split tensile test

From the above figure 2 it can be concluded that the split tensile strength increases with age for both the type of concrete but comparatively the maximum strength developed is for that of natural aggregate with a strength development of 5.63N/mm². The maximum developed tensile strength for recycled aggregate concrete is for that of 20% replacement being 5.85N/mm²

FLEXURE TEST RESULTS: The flexure test indicates a decreasing trend of flexure strength when the percentage of recycled aggregate is increased. Table below shows the average flexure strength recorded during the test.

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Table 6: Flexure test results on concrete

S.no	% replacement	Flexural strength for 7 days (N/mm ²)	Flexure strength for 28days (N/mm ²)
1	0	3.40	4.63
2	10	3.36	4.07
3	20	3.48	4.88
4	30	2.80	3.83
5	40	2.52	3.45

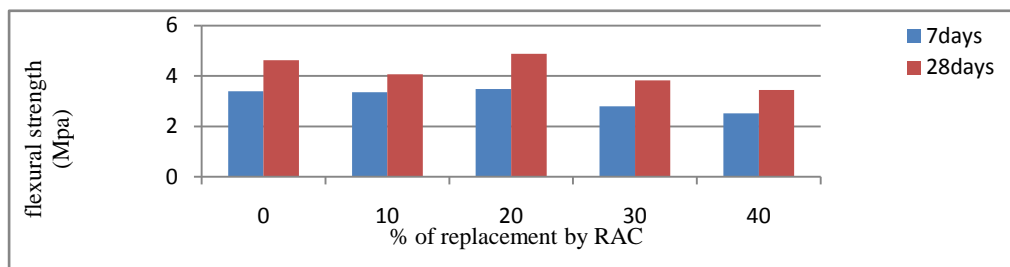


Figure 3: consolidated graph for flexural strength

Flexure strength results from the above figure 3 shows the comparative graph for 7, 28days maximum flexural strength developed in recycled aggregate concrete is again for a replacement of 20% being 4.88N/mm². And the least strength developed is with 40% replacement being 3.45N/mm².

DURABILITY TEST RESULTS:

ACID RESISTANCE TEST:

Three cubes samples are prepared both with NAC and RAC and the weights are noted after 5,10,15,20, and 28 days. The results are presented in the below table.

Table 7: Average weight loss of NAC and RAC cubes subjected to acid attack

DAYS	0	5	10	15	20	25	28
% LOSS FOR NAC	0	3.04	3.87	2.19	1.75	2.63	3.03
% LOSS FOR RAC	0	1.70	2.17	1.73	0.86	2.17	1.30

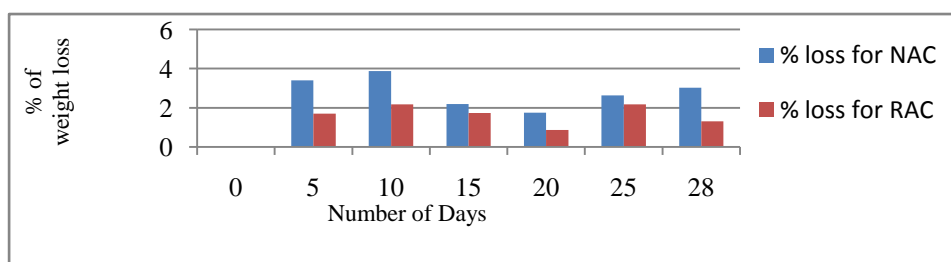


Figure 4: Percentage weight loss with days for NAC and RAC

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From the above figure 4 it can be conclude that exposure to acidic environment causes severe degradation in concrete. As the age of concrete in acidic solution increases, the weight loss also increases as seen in graph. It can also be inferred from the graph that the weight loss in recycled aggregate concrete is less than normal aggregate concrete. Thus we can say that recycled aggregates can be more effective in resisting acids but this also depends on the quality of recycled aggregates.

SULPHATE ATTACK TEST:

Three cubes samples are prepared both with NAC and RAC and the weights are noted after 5,10,15,20, and 28 days. The results are presented in the below table.

Table 8: Average weight loss of NAC and RAC cubes subjected to sulphate attack

DAYS	0	5	10	15	20	25	28
% LOSS FOR NAC	0	1.23	2.41	0.82	0.40	0.81	1.61
% LOSS FOR RAC	0	1.58	0.78	1.55	0.39	0.78	1.17

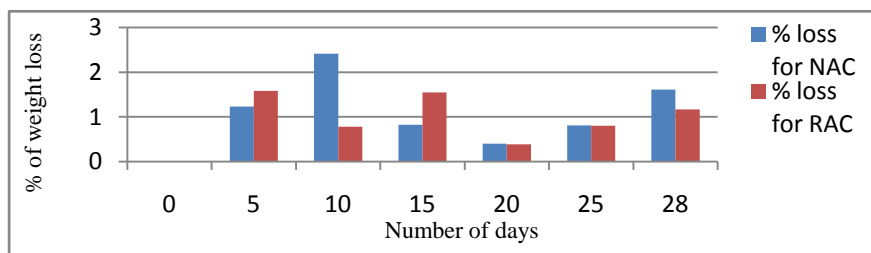


Figure 5: Percentage weight loss with days in NAC and RAC subjected to sulphate attack

It can be concluded from the above figure 5 that in case of specimens subjected to resistance against sulphate attack, the specimens have gained weight with age. In this case the weight gained in case of recycled aggregate concrete is more compared to the weight gained in case normal aggregate concrete. Thus we can assume that recycled aggregates are more prone to sulphate attack than natural aggregates.

CHLORIDE ATTACK: Three cubes samples are prepared both with NAC and RAC and the weights are noted after 5,10,15,20, and 28 days. The results are presented in the below table.

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Table 9: Average weight loss of NAC and RAC cubes subjected to chloride attack

DAYS	0	5	10	15	20	25	28
% LOSS FOR NAC	0	0.81	0.82	1.22	0.80	1.6	1.18
% LOSS FOR RAC	0	1.60	1.2	1.65	0.40	0.81	1.2

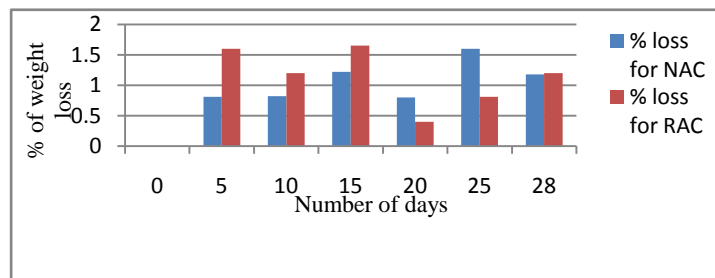


Figure 6: Percentage weight loss with age for NAC and RAC subjected to chloride attack

In case of resistance to chloride attack, the trend is similar to that of sulphate attack. With increase in age of immersion in the solution, there is progressive weight gain in the concrete specimens. In this case the weight gained by natural aggregate concrete is more than the recycled aggregate concrete. The results indicate that RAC is more resistant than NAC when subjected to chloride attack. The graph clearly explains the high variation in weight gain between RAC and NAC. Thus a conclusion can be given that RAC can be used in marine environments.

WATER ABSORPTION TEST:

Table 10: Weight of cubes subjected to water absorption in kg

Cube no	Dry weight-kg	Wet weight-kg
NAC 10	2.33	2.44
NAC 11	2.29	2.40
RAC 10	2.32	2.46
RAC 11	2.31	2.43

Table 11: Percentage gain of weight of cubes subjected to water absorption

Water absorption	
Specimen	% water absorption
NAC 10	3.27
NAC 11	3.45
RAC 10	3.98
RAC 11	3.80

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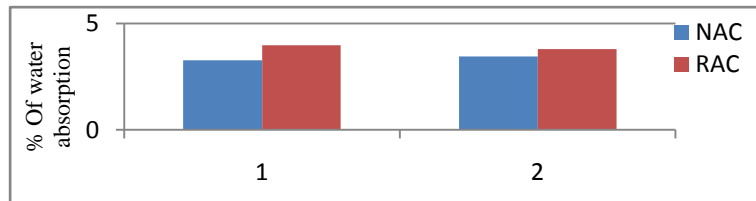


Figure 7: Percentage water absorption for NAC and RAC

From the water absorption test results from above figure 7. It can be concluded that the recycled aggregates have more water absorption than natural aggregate concrete. This can be attributed to the adhered mortar present in the recycled aggregates which have the tendency of absorbing extra water.

COMPRESSIVE STRENGTH AT 28 DAYS AFTER TESTING FOR DURABILITY:

Table 12: Compressive strength for specimens subject to durability tests

Specimen	Compressive Strength at 28 days- N/mm ²
Acid attack-NAC	49.08
Acid attack-RAC	53.22
Sulphate attack-NAC	68.58
Sulphate attack-RAC	71.26
Chloride attack-NAC	62.33
Chloride attack-RAC	73.03

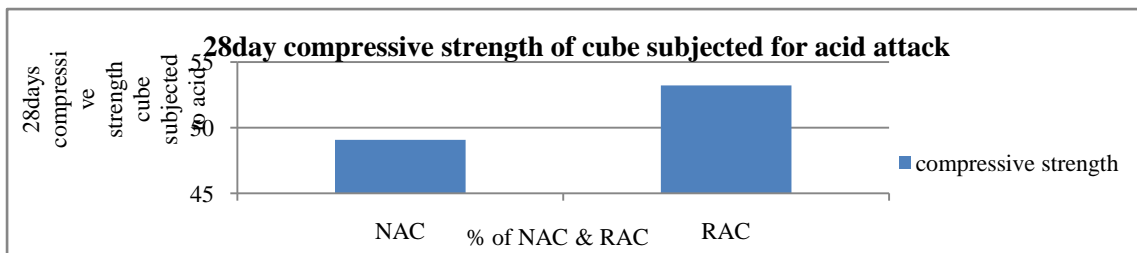


Figure 8: 28 day compressive strength for specimens subjected to acid attack

From the above graph, figure 8 it can be said that the resistance to acid attack is less in both the natural aggregate concrete and recycled aggregate concrete. Both the types of concrete specimens have very less strength, much lower than the target strength at 28 days after immersion in acid solution. The strength of natural aggregate is 49.08% lower than that of the compressive strength for natural aggregate concrete at 28 days. On the other hand the strength of recycled aggregate concrete at 28 days after immersion in acid solution is 53.22% lower than the corresponding recycled aggregate concrete at 28 days curing. The loss in compressive strength and weight is attributed to the fact that Portland cement being highly alkaline is not resistant to attack by strong acids. Hence in mixes having high RCA content, the adhered mortar contributed to high alkalinity which ultimately resulted in reduced resistance to attack by acids.

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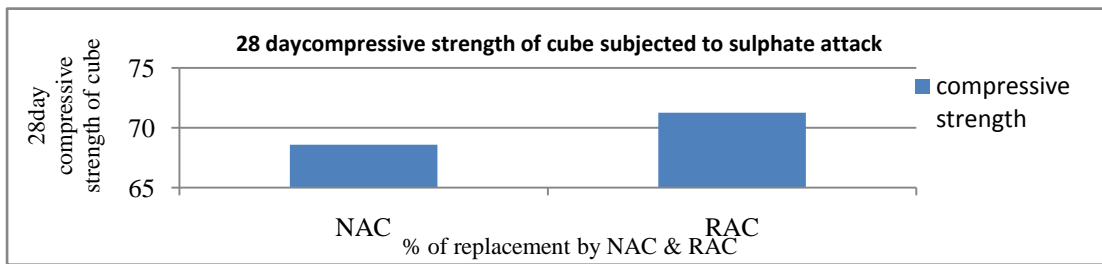


Figure 9: 28 day compressive strength for specimens subjected to sulphate attack

In case of compressive strength of specimens subjected to sulphate attack, we can see a development in compressive strength of specimens. This is attributed to the fact that sulphate enables formation of ettringite which is responsible for good bond development between the mortar and aggregates hence improving the strength of concrete. In case of natural aggregate concrete the compressive strength after 28 days of immersion in sulphate solution, the strength reduction compared to natural aggregate concrete at 28 days curing is only 0.766% which is negligible. Similarly in case of recycled aggregate concrete. The compressive strength reduction of recycled aggregate concrete in sulphate solution has a reduction in strength as compared to recycled aggregate concrete at 28 days of curing is 71.26N/mm².

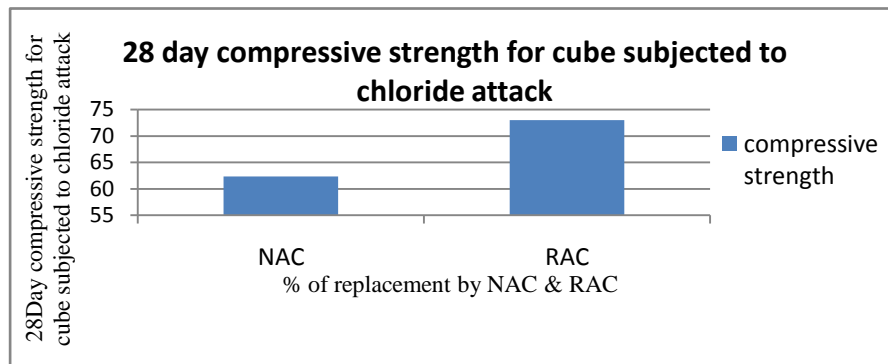


Figure 10: 28 day compressive strength for specimens subjected to chloride attack

In case of specimens subjected to sea water environment, we have put the specimens in chloride solution for a period of 28 days. It can be seen that the natural aggregate specimens have a compressive strength of 48MPa with a reduction in strength of 62.33N/mm² as compared to natural aggregate concrete at 28 days of curing. On the other hand, in case of recycled aggregate concrete, the strength after 28 days of immersion in chloride solution is much more than that of the natural aggregate concrete and it is 73.03MPa.

V. CONCLUSIONS

- The different materials used in the production of high strength concrete have been evaluated for their strength and properties and have been characterized respectively to determine if they are suitable for being used in the production of high strength concrete.

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- The constituents' mainly coarse aggregates, fine aggregates and cement have been tested for their basic properties and it is found that all the results in most cases lie within the expected range.
- The specific gravity of the aggregates must lie in the range of 2.5 to 3.
- The specific gravity of natural coarse aggregates lie within the range and is 2.657
- On the other hand the specific gravity of recycled aggregate concrete is slightly lesser than the range and is 2.469.
- Again the bulk density of the natural aggregates lies in the required range and is 1.55kg/L in compact state and 1.404kg/L in loose state.
- Whereas the bulk density of recycled aggregates is lower than that of natural aggregates similar to specific gravity and is 1.44kg/L in compact state and 1.31kg/L in loose state.
- From the above it can be concluded that both the specific gravity sand bulk density of recycled aggregates is lower than that of the natural aggregates and this can be attributed to the attached mortar present in the recycled aggregates.
- The attached mortar in the aggregates make the aggregate lighter hence reducing the specific gravity and bulk density of it.
- The crushing and impact value tests were performed on the natural aggregates and recycled aggregates.
- All though these tests are usually done on aggregates used in highway construction, we have performed these tests in order to assess the strength of these aggregates.
- This is because the recycled aggregates have already been used in previous construction and will not be as strong as the fresh aggregates.
- The crushing value of natural aggregates is 27.56% while that of recycled aggregates is 28.1%.
- Similarly the impact values of recycled aggregates are higher than the natural aggregates. For natural aggregates it is 21.176% while that of recycled aggregates is 29.66%.
- This is because the recycled aggregates have already been used in previous construction. Hence have lost some strength and strain energy and are subjected to fatigue. Hence they have the tendency to crumble or break easily under load.
- When it comes to water absorption the rate of water absorption is higher in recycled aggregates than conventional aggregates. The rate at which they are higher as compared to that of natural aggregates depends on the nature type and amount of attached mortar present in the recycled aggregates.
- In this case the water absorption of natural aggregates is 0.311% while that of recycled aggregates is 2.24% which is about 6% higher.
- The properties of cement all lay within the required range and it had a specific gravity of 3.279.
- The properties of fine aggregates too lie within the range. From the properties and the gradation of fine aggregates we can conclude that the sand is natural river sand confirming to zone 2 gradation.
- The mix design for high strength was done as per Perumal's method with the water cement ratio being maintained constant.
- The dosage of super plasticizer was maintained 3% for all mixes and was based on the required workability.
- 5 mixes of replacement ratios of coarse aggregates as follows: 0%, 10%, 20%, 30%, and 40% were casted and the workability, strength and durability tests were conducted.
- As the concrete was high strength, the slump was zero.
- From the compaction factor results it can be concluded that the natural aggregate concrete is most workable and the workability reduces with increase in the replacement ratio of coarse aggregates with RA.
- But in all cases the compaction factor was within the range for moderate workable concrete.
- From the compressive strength results of the concrete it can be concluded that both the natural and recycled aggregate concrete gain strength with age.
- But at any instant the strength of recycled aggregate concrete is lower than the strength of natural aggregate concrete.

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- The greater the replacement ratio, the lesser is the strength developed in the concrete.
- The compressive strength of 40% recycled aggregate concrete is 14.36% lower than that of natural aggregate concrete while that of 10% recycled aggregate concrete is just 0.55% lower than that of natural aggregate concrete
- From the compression test results it can be concluded that up to 30% replacement of natural aggregates with recycled aggregates there is no considerable reduction in strength of concrete and hence can be considered as optimum replacement without compromise on strength.
- The same above conclusions follow for split tensile strength and flexural strength of concrete.
- The split tensile strength of 40% RAC is 26.46% lower than that of NAC while the split tensile strength of 10% RAC is 6.75% lower than that of NAC.
- The flexural strength of 40% RAC is 27.45% lower than that of NAC while that of 10% RAC is 3.48% lower than that of NAC.
- Hence from the strength results, 30% replacement is considered as optimum and two sets of cubes- one of NAC and other of 30% replacement RAC were casted for durability tests for a period of 28 days.
- From the test results of acid attack resistance test it can be concluded that under the effect of concentrated hydrochloric acid, the weight loss is rapid and considerable.
- Also the compression test results show a rapid drop in strength of both natural and recycled aggregate concrete under acid attack.
- The strength reduction in NAC under acid attack as compared to NAC after 28 day curing is 39.9% while that of RAC is 46.36%.
- This shows that the RAC have just 50% of their expected strength left after being subjected to acid attack resistance showing very poor performance.
- In case of specimens subjected to sulphate attack, it can be observed that the results are positive as we can see a development in strength with increase in exposure to sulphate solution. This is true in both NAC and RAC although the strength developed in RAC is less than that of NAC.
- The reduction in strength of NAC subjected to sulphate attack as compared to strength at 28 days of curing is only just 0.766% while of that in RAC is 15.57%
- The reason for good strength development in this case is because when the specimens are immersed in sulphate solution, they aid in the formation of ettringite which essentially helps in good strength and bond development in concrete.
- In case of specimens subjected to chloride attack, we can see that the strength development is good again in this case and also further the strength of RAC is in fact better than the NAC after 28 days of immersion in the solution.
- Hence we can conclude that the RAC are more resistant to sulphate and chloride attack.
- In case of water absorption, the RAC exhibit higher water absorption values as compared to NAC. This is due to the presence of attached mortar present in the aggregates. The greater is the attached mortar, the more is the water absorption in the concrete.
- From the above observations it can be concluded that although the values of strength results of RAC is lower than the NAC, they are still within the useable range and by limiting the replacement ratio, the desirable strength can be easily obtained using recycled aggregate concrete also.
- Also from the durability results it can be concluded that the resistance acid attack is poor in RAC as well as NAC. But the RAC perform better under sulphate and chloride attack.

From the above discussions and conclusions we can say that the demolished concrete wastes can be easily used not only in non-structural construction but also in structural concrete too. In fact it can be used in the production of high strength concrete which gives way for new possible research and opportunities in this topic.

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We must consider the possible ways of using the demolished wasted in newer construction as in current situation, not only the strength is important but also sustainability in construction. Hence in order that any construction is sustainable, we must be able to easily accommodate the generated construction wastes in new construction without adversely affecting the environment.

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