International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

DURABILITY STUDIES ON RECYCLED COARSE AGGREGATE CONCRETE OF GRADE M40

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Abstract: *The study presents the mix design for M40 grade concrete. Optimum value for recycled aggregate calculated. The results of strength test (compressive) conducted on Natural coarse aggregate concrete and Recycled coarse aggregate concrete of M40 grade for Normal water curing and sea water curing respectively. The chapter also presents the effect of sea water curing on mechanical properties (compressive strength) of Recycled coarse aggregate concrete of M40 grade. The experimental investigation also presents the durability studies like acid attack, sulphate attack, and alkaline attack of recycled coarse aggregate concrete of grade M40. It is concluded that up to 40% of replacement of recycled coarse aggregate can be safe and gave similar results to compare with natural aggregates in normal water curing and sea water curing. The loss for flexural and split tensile strength is less in sea water curing to compare with normal water curing. For durability studies it is concluded that the loss of strength in acid attack is more to compare with sulphate and alkaline attack.*

Keywords: Recycled aggregate, Mix Design, Concrete, Sea Water Curing & Durability Studies.

1. Introduction: The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal. Lot of marine infrastructure are going to be established along the coast, where sea water is available at least cost. The types of structures built in marine environment are break waters, berths, buildings and jetties etc., which are directly in contact with or subjected to sea water. Concrete durability has been defined by the American Concrete Institute as its resistance to weathering action, chemical attack, abrasion and other degradation processes. Durability is the ability to last a long time without significant deterioration.

2.Literature review:

Prabhat kumar et al (2016) presented a review paper on experimental study for recycle concrete. It is concluded that, from various study recycled aggregate can be used with natural aggregates. Natural aggregate can be used with Recycle aggregate with a ratio of 80:20 and 70:30. Due to use of recycled aggregate in construction industry it can slow the impact of waste on environment.

Jianxiu Wang et al (2013) have performed studies on Mechanical Properties of Recycled Concrete in Marine Environment.it is revealed that RC' peak value and elastic modulus decreased with the increase of replacement percentage and corroding time in marine environment. And the failure of recycled concrete was speeded up with more obvious cracks and larger angles of 65° to 85° in the surface when compared with normal concrete.

V.Ramasamy (2011) has conducted experimental investigation on Compressive Strength and Durability Properties of Rice Husk Ash Concrete. From the durability studies namely chloride permeability, acid attack, alkaline attack and sulphate attack it has been observed that there is an increase in resistance up to 20% replacement of cement by RHA.

3. Experimental studies:

3.1 Cement:

53 grade OPC cement is used in the present work. The properties of cement are determined from the laboratory investigations. The results of tests conducted on cement are presented in Table, along with the permissible limits for ascertaining quality of cement.

Table.1 Physical Properties of Cement

Properties	Results	Permissible limit as per IS:8112-1989
Fineness of Cement	6.2 %	Not more than 10 %
Normal consistency	3 2 %	-
Specific gravity	3.02	-
Initial Setting Time	95 min	Should not be less than 30 min
Final Setting Time	340 min	Should not be more than 600 min
Compressive strength of mortar cubes for		
3 days	28.5 MPa	Should be > 27 MPa
7 days	37.4 MPa	Should be > 37 MPa
28 days	54.1 MPa	Should be > 53 MPa

2 Coarse Aggregate:

A natural and recycled aggregate were used in this study. Natural coarse aggregate (NCA) used was from an established quarry satisfying the requirements of IS 383:1970.

Table.2 Properties of Aggregate

Physical properties	Natural Coarse Aggregate (NAC)
Maximum nominal size graded(mm)	20
Specific gravity	2.78
Water Absorption percent (%) IS:2386 (Part3)-1963	0.50 %
Impact value % IS:2386 (Part4)-1963	18.30%
Aggregate crushing value % IS:2386 (Part4)-1963	21.10%

3.3 Fine Aggregate:

river sand conforming to Zone II as per 383: 1970 was used as fine aggregate.

Table.3 Physical Properties of F.A

Physical properties	Natural fine aggregate
Particulars	River Sand
Zone	Zone II
Specific gravity	2.76
Fineness	2.63
Water absorption	0.50 %

4. Mix Design for M40 Grade concrete:

The concrete mix M40 grade was designed in accordance to IS 10262 - 2009. The mix proportion for M40 concrete was designed by considering the properties of ingredients. The water cement ratio adopted in the present project is 0.45. Design mix of M40 grade for conventional aggregate without recycled aggregate forms the basic reference mix and then the recycled aggregates were replaced by different levels.

Mix Calculation

Target compressive strength of concrete,

$f_t = f_{ck} + k.s$

$= 40 + (1.65 \times 5) = 48.25$ MPa

For 20mm maximum nominal size of aggregate,

Water content = 186 litres for 50 mm slump

= 186 lit

Maximum water cement ratio = 0.45

Cement content $= \frac{Water\ content}{\frac{W}{C}\ ratio}$

$= \frac{186}{0.45} = 410\ kg/m^3$

Volume of cement $= \frac{weight\ of\ cement}{specific\ gravity\ of\ cement} \times \frac{1}{1000}$

$= \frac{410}{3.02} \times \frac{1}{1000}$

$= 0.135$

Volume of Water $= \frac{weight\ of\ water}{specific\ gravity\ of\ Water} \times \frac{1}{1000}$

$= \frac{186}{1} \times \frac{1}{1000}$

$= 0.186$

Volume of aggregate = 1- (volume of water + volume of cement)

= 1- (0.186+0.135)
= 0.679

As per IS 10262, For Zone 2 aggregate (fine and coarse aggregate) proportions are 0.46 & 0.54 respectively.

Volume of coarse aggregate = 0.62×0.679
= 0.421

Volume of fine aggregate = 0.38×0.679
= 0.258

Weight of fine aggregate= Volume of fineaggregate×sp.gravity of fine aggregate×1000

= 0.258×2.76×1000
= 712 kg/m^3

Weight of coarse aggregate = Volume of coarse aggregate×sp.gravity of coarseaggregate×1000
= 0.421×2.78×1000
= 1170 kg/m^3

Proportion = cement: fine aggregate: Coarse aggregate
= 1: 1.74: 2.85

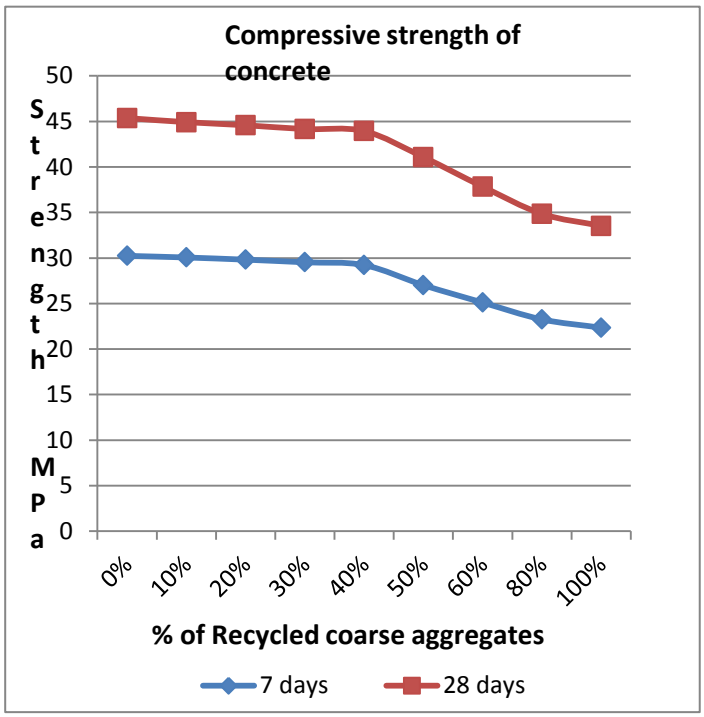
Estimated quantities of materials per cubic meter of concrete are,

Cement = 410 kg
Fine aggregate = 712 kg
Coarse aggregate = 1170 kg
Water = 186 kg

5.Compressive strength of specimens for optimum value

Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per IS 516:1959. The compressive strength is usually obtained experimentally by means of a compressive test.

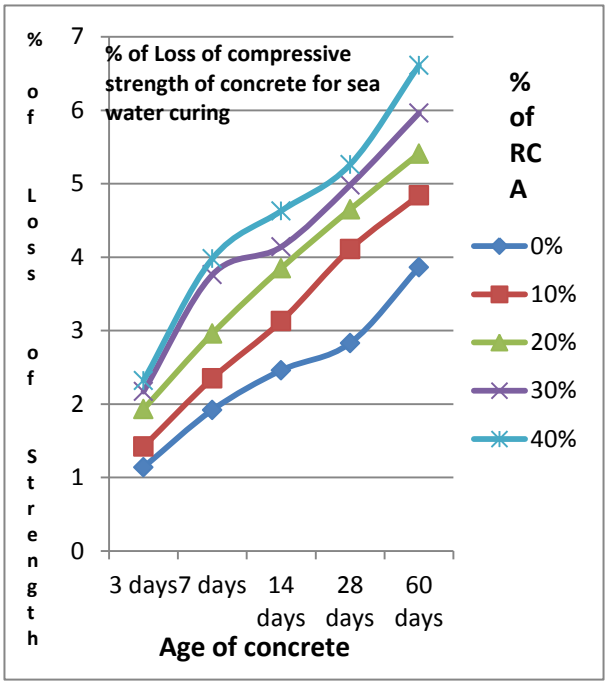
The results shows that the effect of replacement of recycled coarse aggregates on strength of concrete at the age of 7 days and 28 days, it is reported that the strength value decreases from 10% to 40% replacement of recycled coarse aggregate but there is very less reduction in strength upto 40% replacement (i.e less than 4%). A significant reduction (i.e 10% to 27%) in the strength of Recycled Aggregate Concrete (RAC) made of 50% to 100% RCA was seen when compared to Natural Aggregate Concrete (NAC), while the strength of replacement of RCA from 10% to 40% showed no significant change in concrete strength.



Graph.1compressive strength of concrete

5.1 Loss of compressive strength:

Loss of compressive strength of specimens was calculated for sea water curing to compare with normal water curing. The loss of strength was found 1.14%, 1.92%, 2.46%, 2.83% and 3.86% for 3 days, 7 days, 14 days, 28 days and 60 days respectively 0% replacement of RCA. The loss of strength was found 1.42%, 2.35%, 3.13%, 4.11% and 4.84% for 3 days, 7 days, 14 days, 28 days and 60 days respectively at 10% replacement of RCA. The loss of strength was found 1.93%, 2.96%, 3.85%, 4.65% and 5.41% for 3 days, 7 days, 14 days, 28 days and 60 days respectively at 20% replacement of RCA. The loss of strength was found 2.17%, 3.76%, 4.14%, 4.98% and 5.96% for 3 days, 7 days, 14 days, 28 days and 60 days respectively at 30% replacement of recycled coarse aggregate. The loss of strength was found 2.32%, 3.98%, 4.63%, 5.26% and 6.61% for 3 days, 7 days, 14 days, 28 days and 60 days respectively at 40% replacement of recycled coarse aggregate.



Graph.2 loss of strength in sea water

6. Durability tests:

6.1 Acid Attack Test

This test was carried out on specimens of size of 100 mm × 100 mm ×100 mm were cast and stored in a place at a temperature of 27^{O}C ± 2^{O}C for 24 hours and then the demoulded specimens were water cured for 28 days. After 28 days curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken. For acid attack, 5% dilute Hydrochloric Acid (HCl) with pH value of about 1 was used. After that, cubes were immersed in the above said acid water for a period of 28, 60, 90, 120, 150 and 180 days.

6.2 Alkaline Attack test:

This test was carried out on specimens of size of 100 mm × 100 mm ×100 mm were cast and stored in a place at a temperature of 27^{O}C ± 2^{O}C for 24 hours and then the demoulded specimens were water cured for 28 days. After 28 days curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken. For alkaline attack test, Five percent by weight of water of sodium hydroxide (NaOH) was added with water with pH value of about 14 was used. After that, cubes were immersed in the above said base water for a period of 28, 60, 90, 120, 150 and 180 days.

6.3 Sulfate Attack Test

This test was carried out on specimens of size of 100 mm × 100 mm ×100 mm were cast and stored in a place at a temperature of 27^{O}C ± 2^{O}C for 24 hours and then the demoulded specimens were water cured for 28 days. After 28 days curing, the specimens were taken out and allowed to dry for one day. Weights of the cubes were taken. For alkaline attack test, a solution containing five percent of sodium sulphate (Na_2SO_4) and five percent of magnesium sulphate ($MgSO_4$) by weight of water with pH value of about 10 was used. After that, cubes were immersed in the above said base water for a period of 28, 60, 90, 120, 150 and 180 days.

6.4 Durability Test Results

6.4.1 Percentage Loss of Compressive Strength

(With respect to corresponding Normal Water curing value @ 28 days)

Sulphate Attack

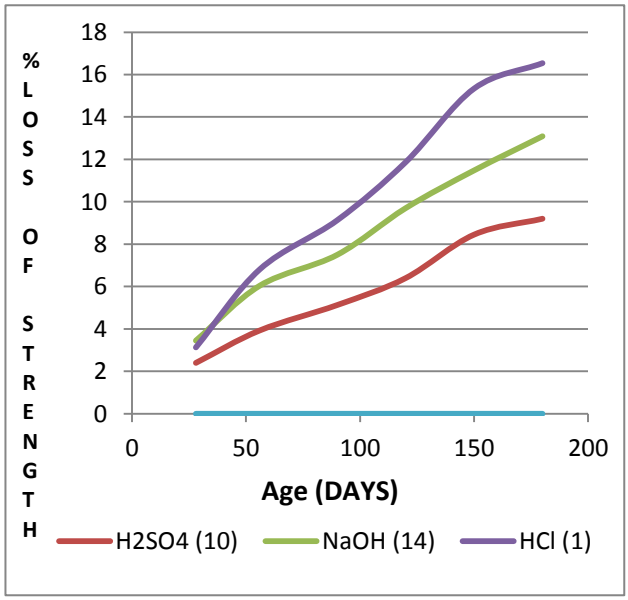
The percentage loss of compressive strength is observed to be 2.40 % for 28 days, 3.93 % for 56 days, 5.13 % for 90 days, 6.40% for 120 days, 8.45 % for 150 days and 9.20 for 180 days respectively. The percentage strength loss is observed to be increasing in correspondence with time.

Alkaline Attack

The percentage loss of compressive strength is observed to be 3.45 % for 28 days, 6.04 % for 56 days, 6.70 % for 90 days, 9.70% for 120 days, 11.48 % for 150 days, 13.09 % for 180 days respectively. The percentage strength loss is observed to be increasing in correspondence with time.

Acid Attack

The percentage loss of compressive strength is observed to be 3.13 % for 28 days, 6.81 % for 56 days, 9.13 % for 90 days, 11.87% for 120 days, 15.34 % for 150 days and 16.54 % for 180 days respectively. The percentage strength loss is observed to be increasing in correspondence with time.



Graph.3 loss of strengths

7 Conclusions

Based on the results of the experimental studies on M40 grade concretes with recycled and natural coarse aggregates and river sand as fine aggregate and taking the effect of curing with normal water and sea water the following conclusions are drawn.

1. As optimum value of 40 % replacement of normal coarse aggregate with recycled coarse aggregate from 0% to 40% is suggested.
2. The maximum loss of compressive strength was found less than 7% when compare with same specimens with same ages of curing (3, 7, 14, 28, 60 days) for normal and sea water curing.
3. The percentage loss of compressive strength of concrete in sulphate attack increases corresponding to the time and it is low value to compare with alkaline and acid attack.
4. The percentage loss of compressive strength of concrete in alkaline attack increases corresponding to the time and it is high value to compare with sulphate attack. It is low value to compare with acid attack.
5. The percentage loss of compressive strength of concrete in acid attack increases corresponding to the time and it is high value to compare with sulphate attack and alkaline attack.

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