An Endeavor to Replace Some of the Cement in Recycled Aggregate Concrete with Flyash and Alocofine

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Abstract
Aggregates that have been recycled are those that have been gathered from demolition and building debris. The manufacturing of demolition trash has increased recently, which has contaminated the ecosystem. Thus, substituting recycled materials for natural aggregates will reduce trash generation. The application of recycled aggregates is expanding daily, which will substantially lower the cost. This paper's major goal is to determine the strength characteristics of recycled aggregates so that they may be utilised as a substitute for natural aggregates. Flyash and alccofine are used to replace some of the binding material in an M40 grade concrete. Here, recycled aggregates are used to make concrete in place of natural aggregates to varying degrees (25%, 50%, 75% and 100%), partial replacement of cement with a flyash (25%) and alccofine (0%, 5%, 10% and 15%). Mix design of binary blended recycled aggregate concrete are done by using IS:10262-2019. Workability is measured and mechanical properties like compressive strength, flexure and split tensile strength were determined for 7days and 28 days. Alkaline attack should be calculated after 28 days of NaOH solution curing. The strength of the concrete is decreased suddenly if the recycled aggregates are increased more than 50%. More than 10% of alccofine content the strength is decreased.
Keywords: Recycled aggregates; Fly ash; Alccofine.

Introduction

Concrete is used to construct the majority of the world's infrastructure. Coarse aggregate makes up a significant portion of concrete. Because natural aggregates are used so frequently, there is a danger of shortage; recycled aggregates are employed to address this. The majority of the structures are in a state of degradation as a result of complicated interactions between concrete and the environment and inadequate upkeep. Then, the buildings are either destroyed or restored. To solve this issue, aggregates are gathered from concrete waste and utilized in place of natural aggregates [1–5]. This debris collects in open places the most. This will result in less environmental contamination. The concept of introducing the recycled aggregate in the concrete is an eco friendly concept and it leads to decrease the cost of the concrete preparation [6,9]. Concept of usage of multiple binding materials, involving solid waste from different sources like fly ash, GGBS and alccofine etc. this pozzolanic materials which serve an excellent replacement for cement, improve the micro structural properties of concrete [7,9].the strength of the recycled aggregates are lesswhen compared to the conventional concrete because of low bonding between cement matrix and aggregate particles, to make bond between them extra materials are introduced. Flyash will gives the low early strength to enhance the strength alccofine is introduced. Recycled aggregates can be considered as a goodreplacement to natural aggregates in concrete [8]. Recycled coarse aggregates, fly ash and alccofine are used many of the laboratory experiments separately [10-15]. Alccofine can reduce the consumption ofcement and carbondioxyde emission in the atmosphere [16]. The present work is an attempt to develop an equivalent ternary blended recycled aggregate concrete using flyash and alccofine as a partial replacement for cement. Alccofine is a micro material which have more calcium oxide and silica content (near to cement chemical composition), similarly fly ash have more silica content. The main function is to prevent segregation and fill micro voids to become concrete make more dense structure.

Objective of research work

1. To study the workability and mechanical properties of binary blended recycled aggregate concrete by adding recycled aggregates by 25%, 50%, 75% and 100% of the weight of the coarse aggregate.
2. To study the mechanical properties of binary blended recycled aggregate concrete by partially replacing cement with alccofine (0%,5%,10% and 15%).
3. To study the alkaline resistance behavior of binary blended recycled aggregate concrete cube specimens, immersed in 3% of NaOH of alkaline solution.

Materials and Methodology

MATERIALS

In this study OPC Cement, coarse aggregate (Natural Aggregates and Recycled Aggregates), robos and , fly ash, alccofine, water and admixtures are used. The physical characteristics of all the materials are as follows.

Cement: The cement used in this study is Ordinary Portland Cement of 53grade from Deccan cement which satisfied the requirements of IS 269:2018. The results of tests conducted on cement are presented in table, along with permissible limits for ascertaining quality of cement.

Table 1: Physical properties of cement

Properties	Results	Permissible limit as per IS:269:2018
Fineness of cement	5.7%	Not more than 10%
Normal consistency	34%	-
Specific gravity	3.15	-
Initial setting time	75 min	Not less than 30 min
Final setting time	480 min	Not more than 600 min
Compressive strength of mortar cubes for		
3 days	27.8MPa	More than 27MPa
7 days	38.6MPa	More than 37MPa
28 days	54.4MPa	More than 53MPa

Coarse aggregate: Natural and Recycled aggregates were used in this study. Natural coarse aggregates used from an established quarry satisfying the requirements of IS: 383-201

Table 2 : physical properties of coarse aggregate.

Physical Properties	Natural Coarse Aggregate (NCA)	Recycled Coarse Aggregate(RCA)
Maximum nominal size in mm	20	20
Specific gravity	2.705	2.68
Water Absorption (%) IS:2386(part3)-1988	0.79	2.63
Impact value % IS:2386(part4-1988	18.56	-
Aggregate crushing value % IS:2386(part4)-1988	21.23	-

Fine aggregate: Robo sand, which is used as a fine aggregate.

Table 3: Physical properties of fine aggregate

Physical properties	Fine aggregate
Particulars	Robo sand
Zone	Zone II (IS:383-2016)
Specific gravity	2.423
Fineness	2.78
Water absorption	13.72%

Fly ash: fly ash was brought from locally available ready mix plant (Build mate Projects Private Limited).specific gravity is 2.6

Table 4 : Physical properties of Flyash

Chemical Composition	Percentage (%)
CaO	3.5
SiO2	49.56
Al2O3	29.54
Fe2O3	10.75
SO3	0.29
MgO	1.2

Alccofine: alccofine1203 was collected from Ambuja cement. Specific gravity is 2.71.

Table 5 : Physical Properties of alccofine

Chemical composition	Percentage (%)
SiO_2	35.3
MgO	6.1
Al_2O_3	21.5
Fe_2O_3	1.3
SO_3	013
Na_2O	32.1

Water: water is a very sensitive and vital raw ingredient for ensuring concrete workability.

Methodology:

The quantities of cement, fly ash, alccofine, fine aggregate and natural coarse aggregates are taken and determined the physical properties. Recycled aggregates are collected and cleaned manually with mortar free and calculated the physical properties and design the concrete mix of M40 based on IS:10262-2019. The material proportion for $1m^3$ of concrete of M40 is listed in Table 6. Recycled aggregate ternary blended concrete specimens of 25%Flyash and 25%RCA, 25%Flyash and 50%RCA, 25%Flyash and 75%RCA, 25%Flyash and 100%RCA and further, above 4 variations undergoes with addition of 5%, 10% and 15% of alccofine. Workability (Slump) of the concrete is measured. Cubes, cylinders and prisms are casted. Mechanical properties are determined at 7 days and 28 days of water curing. Alkaline attack was measured by immersing the concrete cubes in 3% of NaOH solution. After 28 days of curing the tests are performed to calculate the alkaline attack resistant of the concrete.

Table 6**:** Mix proportion of materials for ternary blended recycled aggregate concrete.

Mix no	Mix description OPC%+fly ash%+alccofine%+recycled aggregate%+Natural aggregate%	water	cement	Fly ash	alccofine	Fine aggregate	Natural aggregate	Recycled aggregates
CC	100%+0%+0%+0%+100%	154.56	425.062		-	598.005	1185.87	-
RC1	75%+25%+0%+25%+75%	154.56	318.79	106.26	-	598.005	889.4	296.46
RC2	75%+25%+0%+50%+50%	154.56	318.79	106.26	-	598.005	592.93	592.93
RC3	75%+25%+0%+75%+25%	154.56	318.79	106.26	-	598.005	296.46	889.4
RC4	75%+25%+0%+100%+0%	154.56	318.79	106.26	-	598.005	-	1185.87
RC5	70%+25%+5%+25%+75%	154.56	297.54	106.26	21.25	598.005	889.4	296.46
RC6	70%+25%+5%+50%+50%	154.56	297.54	106.26	21.25	598.005	592.93	592.93
RC7	70%+25%+5%+75%+25%	154.56	297.54	106.26	21.25	598.005	296.46	889.4
RC8	70%+25%+5%+100%+0%	154.56	297.54	106.26	21.25	598.005	-	1185.87
RC9	65%+25%+10%+25%+75%	154.56	276.29	106.26	42.5	598.005	889.4	296.46
RC10	65%+25%+10%+50%+50%	154.56	276.29	106.26	42.5	598.005	592.93	592.93
RC11	65%+25%+10%+75%+25%	154.56	276.29	106.26	42.5	598.005	296.46	889.4
RC12	65%+25%+10%+100%+0%	154.56	276.29	106.26	42.5	598.005	-	1185.87
RC13	60%+25%+15%+25%+75%	154.56	255.03	106.26	63.75	598.005	889.4	296.46
RC14	60%+25%+15%+50%+50%	154.56	255.03	106.26	63.75	598.005	592.93	592.93
RC15	60%+25%+15%+75%+25%	154.56	255.03	106.26	63.75	598.005	296.46	889.4
RC16	60%+25%+15%+100%+0%	154.56	255.03	106.26	63.75	598.005	-	1185.87

RESULTS

The results obtained for the tests conducted on M40 grade of concrete in addition with a replacement of coarse aggregates with recycled aggregates and partially replacement of cement with fly ash (25%) and alccofine (0%, 5%, 10%, 15%).

Workability: After mixing of the concrete the mixture is placed in slump cone with a three layers andeach layer has 25 blows. After filling the cone is lifted and measured the falling height of the concrete. Slump values are listed below.

Table 7: slump values of recycled binary blended concrete in mm

Mix no	Slump value in mm
CC	98
RC1	94
RC2	86
RC3	79
RC4	67
RC5	92
RC6	84
RC7	76
RC8	65
RC9	91
RC10	83
RC11	74
RC12	62
RC13	89
RC14	79
RC15	68
RC16	59

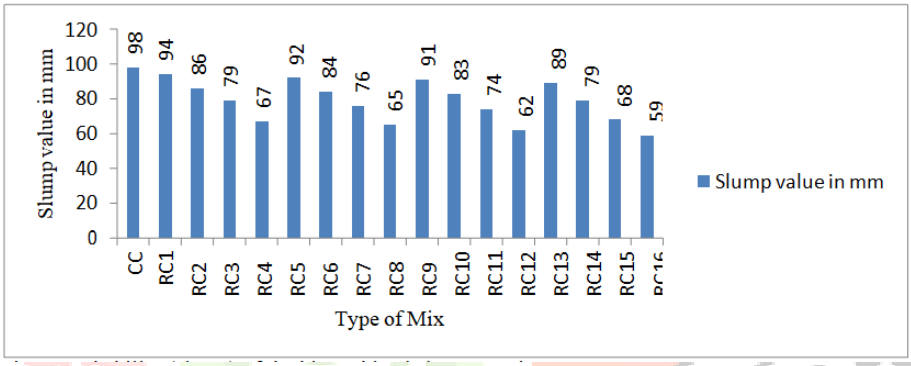


Fig 1: workability (slump) of the binary blended concrete in mm

From graph 1 shows the variation in the workability of the conventional concrete and binary blended recycled aggregate concrete.98mm slump is observed for the conventional mix. 94mm, 86mm, 79mm and 67mm are the slump values observed at mixes RC1 to RC4 respectively. The slump values are reduced to 4.08%, 12.24%, 19.38% and 31.63% respectively. 92mm, 84mm, 76mm and 65 mm arethe slump values observed at mixes RC5 to RC8 respectively. The slump values are reduced to 6.12%, 14.28%, 22.44% and 33.67% respectively. 91mm, 83mm, 74mm and 62mm are the slump values observed at mixes RC9 to RC12 respectively. The slump values are reduced to 7.14%, 15.3%, 24.48% and 36.73% respectively. 89mm, 79mm, 68mm and 59mm are the slump values observed at mixes RC13 to RC16 respectively. The slump values are reduced to 9.18%, 19.38%, 30.61% and 4139.79% respectively.

The workability (slump) values of the binary blended concrete are decreased by increasing the percentage of recycled aggregate content and alccofine content. Due to the high water absorption the workability of the concrete is decreased.

Compressive Strength

Compressive strength of concrete was determined by testing the cube specimen of size 150mm x 150mm x 150mm under compressive testing machine. The compressive test results of prepared specimens are tabulated in Table 6. The tests were conducted as per IS: 516-1959.

Table 8: compressive strength of recycled binary blended concrete at 7 days and 28 days (MPa)

Mix no.	7days	28 days
CC	28.64	48.31
RC1	23.18	38.6
RC2	21.9	36.4
RC3	18.63	31.02
RC4	16.12	26.8
RC5	25.26	44.3
RC6	23.03	42.1
RC7	20.17	37.7
RC8	18.32	31.2
RC9	28.72	48.32
RC10	26.21	44.6
RC11	23.06	39.3
RC12	19.93	33.9
RC13	24.4	40.9
RC14	22.01	38.6
RC15	21.2	31.4
RC16	19.45	27.4

From graph 2, 7days and 28 days of compressive strength of conventional concrete and ternary blended recycled aggregate concrete were shown. 7 days strength of conventional concrete (CC) is observed as 28.64MPa. Mixes RC1 to RC4, 7 days compressive strengths were achieved 23.18MPa, 21.9MPa, 18.63MPa and 16.12MPa respectively, strength is decreased to 19.06%, 23.53%, 34.95% and 43.71% . Mixes RC5 to RC8, 7 days compressive strength of concrete were 25.26MPa, 23.03MPa, 20.17MPa and 18.32MPa respectively; strength is decreased to 11.08%, 19.58%, 29.5% and 36.03%. Mixes RC9 to RC12, 7 days compressive strength of concrete is 28.72MPa, 26.21MPa, 23.06MPa and 19.93MPa respectively, strength is increased to 0.27% and then decreased to 8.48%, 19.48% and 30.41%. Mixes, RC13 toRC16, 7 days compressive strength is recorded as 24.4MPa, 22.01MPa, 21.2MPa and 19.45MPa respectively, strength is decreased to 14.8%, 23.14% , 25.97% and 32.08%.

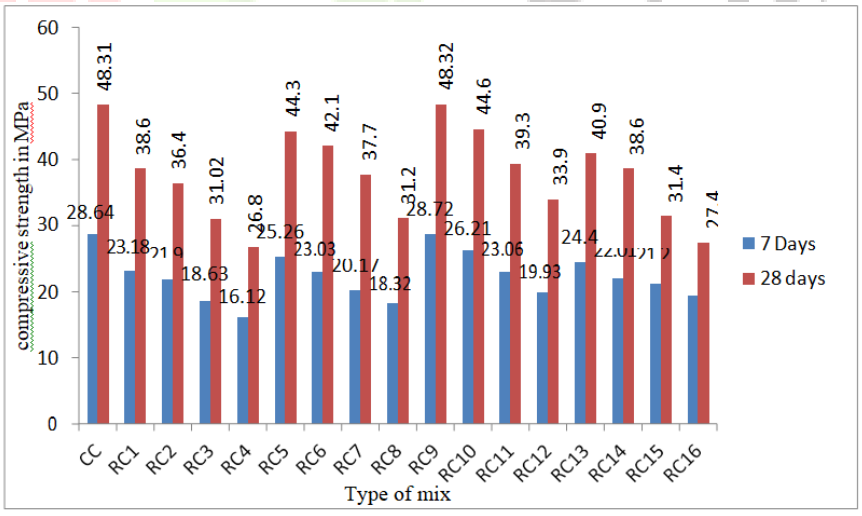


Fig 2: compressive strength of binary blended recycled aggregate concrete at 7 Days and 28Days

28 days compressive strength, conventional concrete (CC) is observed as 48.31MPa. Mixes RC1 to RC4, 28 days compressive strengths were achieved 38.6MPa, 36.4MPa, 31.02MPa and 26.08MPa respectively, strength is decreased to 20.09%, 24.65%, 35.78 and 46.01% . Mixes RC5 to RC8, 28 days compressive strength of concrete were 44.3MPa, 42.1MPa, 37.7MPa and 31.2MPa respectively; strength is decreased to 8.3%, 12.85%, 21.96 and 35.41%. Mixes RC9 to RC12, 28 days compressive strength of concrete is 48.32MPa, 44.6MPa, 39.3MPa and 33.9MPa respectively, strength is increased to 0.02% and then decreased to 7.67%, 18.65% and 29.82%. Mixes, RC13 toRC16, 28 days compressive strength is recorded as 40.9MPa, 38.6MPa, 31.4MPa and 27.4MPa respectively, strength is decreased to 15.33%, 20.09%, 35% and 43.28%.

The compressive strength of the concrete is decreased if the percentage of the recycled aggregates is increased, due to the low weight and less bonding between aggregates and mortar matrix. Similarly the strength of the concrete is increased by increasing alccofine content up to 10% replacement. Further incremental the matrix content is more so the strength of the concrete is decreased.

Flexure strength

Flexure strength of concrete was determined by testing the beam specimen of size 100mm x 100mm x 500mm. The tests are conducted based on IS:516-1959.$\mathbf{F=PL/bd^2}$, where P is the applied load, L is the length of the beam (400mm), b & d are the cross section properties of the beam specimen.

Table 9: Flexural strength of recycled binary blended concrete at 7 days and 28 days.

Mix no.	7days	28 days
CC	2.81	4.63
RC1	2.58	4.3
RC2	2.35	3.92
RC3	2.21	3.76
RC4	2.07	3.63
RC5	2.69	4.45
RC6	2.57	4.32
RC7	2.43	4.29
RC8	2.2	3.83
RC9	2.79	4.62
RC10	2.64	4.41
RC11	2.51	4.36
RC12	2.32	4.02
RC13	2.56	4.32
RC14	2.39	4.09
RC15	2.27	3.87
RC16	2.09	3.42

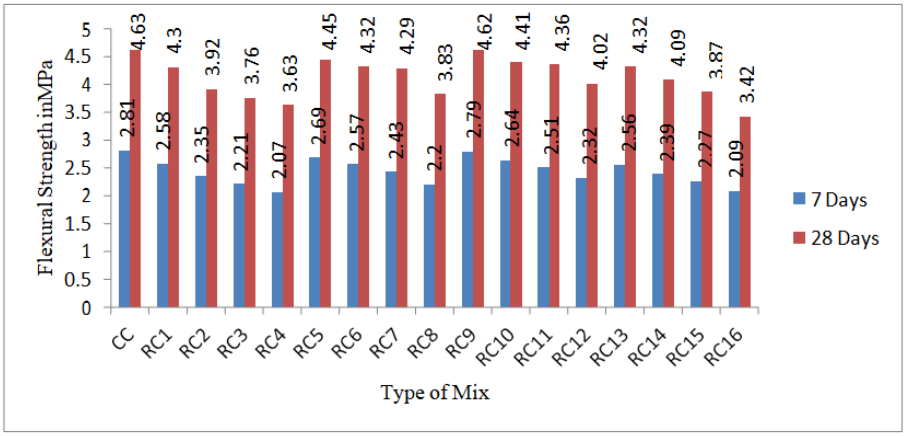


Fig 3: flexural strength of binary blended recycled aggregate concrete at 7 Days and 28Days

From graph 3, 7days and 28 days of flexural strength of conventional concrete and binary blended recycled aggregate concrete were shown. 7 days strength of conventional concrete (CC) is observed as 2.81MPa. Mixes RC1 to RC4, 7 days flexural strengths were achieved 2.58MPa, 2.35MPa, 2.21MPa and 2.07MPa respectively; strengths are reduced to 8.18%, 16.37%, 21.35% and 26.33% respectively. Mixes RC5 to RC8, 7 days flexural strength of concrete were 2.69MPa, 2.57MPa, 2.43MPa and 2.2MPa respectively, strength values are decreased at the percentages of 4.27%, 8.54%, 13.52% and 21.7% respectively. Mixes RC9 to RC12, 7 days flexural strength of concrete is 2.79MPa, 2.64MPa, 2.51MPa and 2.32MPa respectively, strength is decreased to 0.71%, 6.04%, 10.67% and 17.43% respectively. Mixes, RC13 toRC16, 7 days flexural strength is recorded as 2.56MPa, 2.39MPa, 2.27MPa and 2.09MPa respectively, strength values are decreased to 8.89%, 14.94%, 19.21% and 25.62% respectively.

28 days flexural strength, conventional concrete (CC) is observed as 4.63MPa. Mixes RC1 to RC4, 28 days flexural strengths were achieved 4.3MPa, 3.92MPa, 3.76MPa and 3.63MPa respectively, strength is decreased to 7.12%, 15.3%, 18.79% and 21.59%. Mixes RC5 to RC8, 28 days flexural strength of concrete were 4.45MPa, 4.32MPa, 4.29MPa and 3.83MPa respectively, strength is decreased to 3.88%, 6.69%, 7.34% and 17 27%. Mixes RC9 to RC12, 28 days flexural strength of concrete is 4.62MPa, 4.41MPa, 4.36MPa and 4.02MPa respectively, strengths are decreased to 0.21%, 4.75%, 5.83% and 13.17%. Mixes, RC13 toRC16, 28 days flexural strength is recorded as 4.32MPa, 4.09MPa, 3.87MPa and 3.42MPa respectively, strengths are decreased to 6.69%, 11.66%, 16.41% and26.13%.

The flexural strength of the binary blended concrete is decreased by increasing the recycled aggregate content. Up to 10% replacement of alccofine the strength is increased further it decreased due to the high fine material in the concrete.

Split Tensile strength

Split tensile strength of concrete was determined by testing the cylinder specimen of size 150mm diameter and 300mm height under compressive testing machine. This test were conducted as per IS: 1199-1959 and results are shown in the below table. **F=2P/(3.14 x d x L)**, where P is the applied load, d & L are the diameter and length or height of the cylinder.

Table 10: Split Tensile strength of recycled binary blended concrete at 7 days and 28 days

Mix no.	7days	28 days
CC	2.73	4.8
RC1	2.42	4.25
RC2	2.33	4.13
RC3	2.09	3.87
RC4	1.84	3.62
RC5	2.67	4.43
RC6	2.53	4.21
RC7	2.21	4.08
RC8	1.94	3.76
RC9	2.72	4.78
RC10	2.71	4.79
RC11	2.21	4.36
RC12	1.99	4.09
RC13	2.45	4.51
RC14	2.34	4.38
RC15	1.93	4.13
RC16	1.86	3.97

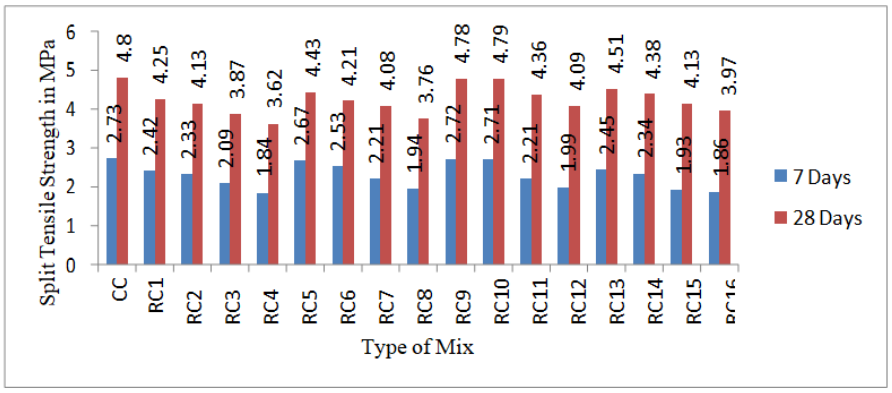


Fig 4: split tensile strength of binary blended recycled aggregate concrete at 7 Days and 28Days

From graph 4, 7days and 28 days of tensile strength of conventional concrete and binary blended recycled aggregate concrete were shown. 7 days strength of conventional concrete (CC) is observed as 2.73MPa. Mixes RC1 to RC4, 7 days tensile strengths were achieved 2.42MPa, 2.33MPa, 2.09MPa and 1.84MPa respectively; strengths are decreased to 11.35%, 14.65%, 23.44% and 32.6%. MixesRC5 to RC8, 7 days tensile strength of concrete were 2.67MPa, 2.53MPa, 2.21MPa and 1.94MPa respectively; strengths are decreased to 2.19%, 7.32%, 19.04% and 28.93%. Mixes RC9 to RC12, 7 days tensile strength of concrete is 2.72MPa, 2.71MPa, 2.21MPa and 1.99MPa respectively; strengths are decreased to 0.36%, 0.73%, 19.04% and 27.1%. Mixes, RC13 toRC16, 7 days tensile strength is recorded as 2.45MPa, 2.34MPa, 1.93MPa and 1.86MPa respectively; strengths are decreased to10.25%, 14.28%, 29.3% and 31.86%.

28 days tensile strength, Strength of conventional concrete (CC) is observed as 4.8MPa. Mixes RC1 to RC4, 28 days tensile strengths were achieved 4.25MPa, 4.13MPa, 3.87MPa and 3.62MPa respectively; strengths are decreased to 11.45%, 13.95%, 19.37% and 24.58%. Mixes RC5 to RC8, 28 days tensile strength of concrete

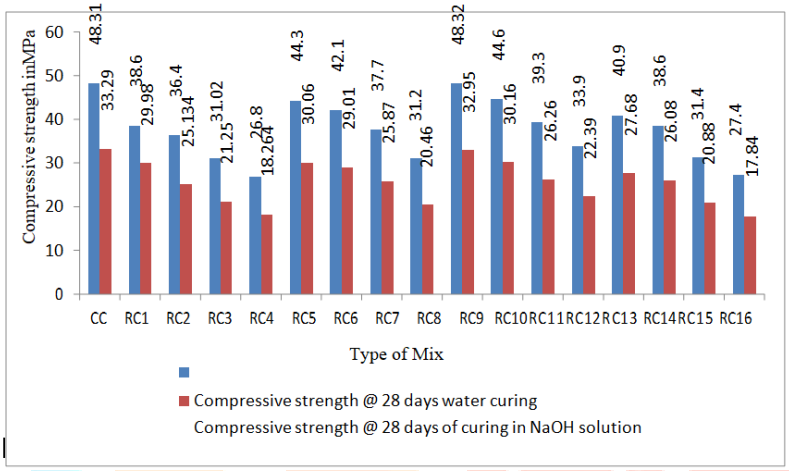
were 4.43MPa, 4.21MPa, 4.08MPa and 3.76MPa respectively; strengths are decreased to 7.7%, 12.29%, 15% and 21.67%. Mixes RC9 to RC12, 28 days tensile strength of concrete is 4.78MPa, 4.79MPa, 4.36MPa and 4.09MPa respectively; strengths are decreased to 0.41%, 0.2%, 9.16% and 14.79%. Mixes, RC13 toRC16, 28 days tensile strength is recorded as 4.51MPa, 4.38MPa, 4.13MPa and 3.97MPa respectively; strengths are decreased to6.04%, 8.75%, 13.95% and 17.29%.

The split tensile strength of the binary blended concrete is decreased goes on increasing the percentage of the recycled aggregate content.

Alkaline attack:

Alkaline attack is tested for determining the alkaline resistance of concrete, the cubes of 100mm x 100mm x 100mm is casted and immersed in sodium hydroxide (NaOH) solution and the tests were conducted after 28 days.

Table 11: loss in strength after 28 days of alkaline solution curing



Mix no	Compressive strength@ 28 days water curing	Compressive strength @ 28 days of curing in NaOH solution	% loss in strength@ 28 days of alkaline solution curing
CC	48.31	33.29	31.09
RC1	38.6	29.98	30.07
RC2	36.4	25.134	30.95
RC3	31.02	21.25	31.49
RC4	26.8	18.264	31.85
RC5	44.3	30.06	30.56
RC6	42.1	29.01	31.10
RC7	37.7	25.87	31.36
RC8	31.2	20.46	34.4
RC9	48.32	32.95	31.8
RC10	44.6	30.16	32.36
RC11	39.3	26.26	33.18
RC12	33.9	22.39	33.94
RC13	40.9	27.68	32.32
RC14	38.6	26.08	32.41
RC15	31.4	20.88	33.49
RC16	27.4	17.84	34.89

Conclusions

The study's analysis of the experimental findings led to the following observations and conclusions.

At 25% replacement of natural aggregates with recycled aggregates, 25% fly ash, 0% alumina fines, and 75% cement content, the maximum workability (slump) is shown.

Compressive strength is greatest when natural aggregates are replaced by recycled aggregates by 25%, fly ash by 25%, alcofine by 10%, and cement by 65%.

Maximum flexural strength is seen with 25% fly ash replacement, 25% recycled aggregate replacement, 10% alocfine replacement, and 65% cement content.

At 50% replacement of natural aggregates with recycled aggregates, 25% fly ash, 10% alccofine, and 65% cement content, split tensile strength reaches its maximum.

Up to 10% replacement of alccofine gives better results, further increment leads to decreasing the strength, because of pozzolanic content will increased. Because of the ultra fine it.

25% replacement of the recycled aggregates adequate further increment leads to less strength because of its low crushing strength and high water absorption.

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