Enrichment of the properties of Concrete mixes containing Reclaimed Asphalt Pavement (RAP) aggregates & Silica Fume – A Laboratory Investigation.

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Abstract - *During the recycling of flexible pavement, an enormous amount of Reclaimed Asphalt Pavement (RAP) aggregate accumulates, which is dumped legally and illegally in the surrounding communities, posing several challenges for agencies. Utilization of these aggregates in cement concrete pavements seems to be a novelistic approach and could facilitate with many socio-economic-environmental benefits.*

In this study, conventional concrete is made using recycled aggregates with additional of micro silica as admixture in concrete. The concrete mix is designed for target strength of M40 MPa. Coarse aggregate were partially with RAP aggregate at 30 %, 45 % and 75%. The relative parameters influencing the strength of concrete were studied in terms of RAP aggregate and silica content respectively. In some studies the test results reveled concrete produced with 45% of RAP aggregate tend to reduce the strength by 15% whereas addition of silica fume up to (4-10%) enhances the strength comparable to control mix (M40). The addition of micro silica improves the physical and mechanical properties of concrete by micro filling the unreacted core. The significant reduction in compressive strength is noticed, when the RAP aggregate is increased beyond 30%

***Key Words*:** Road construction, Reclaimed asphalt pavement, Cement concrete, Compressive strength, Silica fume, Review, Performance, Durability etc.

1. INTRODUCTION

As we know that Urbanization is growing in the present days, where people are looking for a comfortable life with safe shelter and well-connected roads for transportation. To meet these basic needs people are heavily dependent on the natural resources. Most of the reclaimed asphalt pavement is thrown or stored in landfills, destroying a bit more of the environment by increasing pollution. Hence, RAP concretes mixtures can be considered as the most economic and ecological materials in a sustainable development context. Thus, standardised tests for conventional concretes can be carried out to assess the mechanical properties of RAP concretes. It should be noted that the experimental results showed that RAP concretes are similar to conventional concretes in terms of shear stress and shear rate behaviour. In order to improve the properties of concretes, many admixtures can be used. Reusing reclaimed asphalt pavement in cement concretes is still an uncommon practice, but it is a procedure to be encouraged. In this current project we are going to use M40 Grade of concrete. M40 Grade of Concrete is prepared by using design mix. Mix design of M40 grade of concrete is as per IS Code 10262:2009._So, M40 signifies that the structure erected with this grade of concrete will have a minimal strength of 40 N/mm2 after 28 days.. The higher the number, the stronger the material. The fifth ingredient must be added to the concrete mix to improve certain properties both in plastic and hardened states. Adding SF (Silica Fume) modifies the characteristics and the behaviour of fresh concretes and hardened concretes. Once established, it enables the prediction of the compressive strength of concrete with different RAP and SF contents, in the explored fields.

Therefore use of SF in concretes totally or partially by adding RAP aggregates in a concrete mix, experimental results reported that shown a significant increase in the compressive strength; even if the compressive strength decreases when recycled aggregate content increases in mix, by adding silica fume is a good way to improve it. However, there may be need to produce concrete with a particular result by using admixture and RAP aggregates could be most convenient way.

1.1 Problem Statement

The huge development of urban highways and roads has left behind a great amount of wasted materials which is been replaced with new materials. One of these left behind materials is asphalt pavement. The main usage of RAP is to be filled as sub-base material at the reconstruction process or use them as embankment fill material. The disintegration of RAP beneath the ground touches a serious environmental issue. There comes the application of using RAP as partial replacement of natural course aggregate in concrete mix.

1.2 Project Objectives

1. To identify the workability of fresh concrete containing Recycled Asphalt Pavement (RAP).

2. To determine the optimum replacement percentage of Recycled Asphalt Pavement (RAP) as coarse aggregate in concrete mix.

3. To investigate the compressive strength of concrete mix containing Recycled Asphalt Pavement (RAP) and compare it with concrete mix containing 100% of natural coarse aggregate (the control).

4. To investigate the effect of replacement of cement by Micro-Silica on RAP aggregate concrete.

5. To investigate the effect of replacement of cement by Micro-silica on fresh properties of Recycled Asphalt Pavement aggregate concrete

6. To investigate the effect of Micro-silica on compressive strength of concrete.

1.3 Scope of Work

This study concentrated on the performance of a single gradation of RAP. The asphalt pavement samples were collected from Thane-Belapur Road near Ghansoli Railway Station and manually crushed into pieces in J.kumar Laboratories near BKC to achieve a uniform size of 5mm-20 mm, which is the maximum aggregate size in the mix design. All the RAP samples are chosen in Laboratory of J. kumar infraprojects, to avoid any inconsistent properties that may arise by mixing materials from different sources. The properties of RAP from other outside were not included in this study. The selection of the aggregate and cube sizes were determined according to the codes of practice from IS Code 10262:2009. The study was conducted on concrete samples containing RAP incorporated into Portland cement. The influence of using RAP in high strength concrete was not covered in the present study. The percentage replacements are limited to three levels: 30, 45 and 70% replacement of natural coarse aggregate. The different effects, which can be observed at different percentages of replacements, will be compared in the present study. So the scope of study can be follow as;

1. Design of RAP Concrete mix with 7, 14 & 28 days characteristic strength of concrete of 40 N/mm2

2. Use different percentages of RAP as coarse aggregate replacement: 30%, 45% and 75%

3. Fresh concrete test using Slump test to identify concrete workability.

4. Hardened concrete test using Compressive test to determine concrete compressive strength**.**

2. LITERATURE SURVEY

Solomon Debbarma, M. Selvam, Surender Singh – Can flexible pavements' waste (Rap) be utilized in cement concrete pavements? A critical review – This paper focuses on Reclaimed Asphalt Pavement (Rap) aggregates prediction using flexible pavements in concrete mixes with a specific implementation of the Performance & Durability Approach. As a result, this paper presents a comprehensive and critical analysis of the suitability of RAP for concrete mix production. In addition, it identifies the various gaps that need to be addressed to make pavements more sustainable. [1]

M.N. Balakrishna, Fouad Mohamad, Robert Evans, M.M. Rahman – Durability of Concrete with differential Concrete Mix Design – The aim of the present research was to examine the influence of uni-directional exposure of concrete cubes to water absorption to evaluate different mixtures proportion. Seventy-two concrete cubes with different grades of concrete were prepared and evaluate the rate of absorption characteristics in concrete mixtures design. [2]

M.T. Tiza1, O.N. Mogbo, E.C. Duweni3 J.I. Asawa – Recycled Asphalt Pavement: A systematic Literature Review – This review paper aims to build an insight into the interaction between new and aged asphalt binders in Reclaimed Asphalt Pavement (RAP). This research examines the differences in asphalt properties when Reclaimed Asphalt Pavement (RAP) is used as aggregate, and compares the result to natural aggregate. [3]

Rim Larbi, El Hadi Benyoussef, Meriem Morsli, Mahmoud Bensaibi, Abderrahim Bali1 –Improving the Compressive Strength of Reclaimed Asphalt Pavement Concretes with Silica Fume – Using silica fume (SF) as a mineral admixture in RAP concrete is the main objective of the present study. Experimental results show that SF increases the compressive strength of RAP concrete as well as conventional concretes. [4]

Anurag Jain, Student, GHRCE, Nagpu, P. Y. Pawade, PhD HOD Dept. of Civil Engineering GHRCE, Nagpur – Characteristics of Silica Fume Concrete – The paper describes the results of compressive strength tests performed on four and six year-old concrete cores obtained from well-documented field experiments using both silica-fume and non-silica fume concrete mixtures. An optimal silica-fume content was identified at which concrete strength increased significantly.. This paper deals with a literature review on Characteristics of Silica Fume Concrete. [5]

K. E. Hassan, J. J. Brooks and M. Erdman – The use of reclaimed asphalt pavement (RAP) aggregates in concrete – The paper presents the results of a laboratory test of ordinary Portland cement concrete made from reclaimed asphalt pavement (RAP) in place of natural aggregates. To achieve optimum performance, RAP aggregates were combined with concrete based on maximum packing to ensure minimal voids in the mixture. [6]

3. MATERIAL USED

3.1 Cement

In this study, Ordinary Portland Cement (OPC) 53 grade conforming IS 12269-2004 obtained from J. Kumar Laboratory (BKC). Physical properties of cement used in this study are given in Table -1

Table -1: Physical properties of OPC-53 grade

Test	Results
Consistency	32% (30-35%)
Soundness	2mm not more than 10mm
Initial setting time	40min – not less than 30min
Final setting time	460min – 600min (max)as per IS code 4031 part-5
Specific gravity	3.12 ≤ 3.15
Fineness	7% Sieve test on 90µSieve as per {IS 4031 Part-1) < 10%
Compressive strength (28 days)	53 N/mm2

3.2 Fine Sand (Crushed Sand)

Fine aggregate is made from crushed sand. According to IS 383-2004, the sand used here belongs to zone-II. Physical properties of fine aggregate used in this study are given in Table -2

Table -2: Physical properties of Crushed sand

Test	Result
Specific gravity	2.71
Bulk density kg/m3	1534
Water absorption %	2.93%
Moisture content %	1.00%
Fineness modulus	3.866
Grading Zone	II

3.3 Coarse Aggregate

Crushed stone pieces of maximum nominal size of 20mm & 10mm down were used as coarse aggregates confirming to IS 383- 2004. Physical properties of coarse aggregate used in this study are given in Table -3

Table -3: Physical properties of coarse aggregate

Sr.No	Tests	Results	Requirements	ISCodes
1	Specific gravity 20mm & 10mm	2.76 (20mm) 2.74 (10mm)	-	IS-2386 Part III
2	Crushing Value	28.1%	shall not exceed 45% non-wearing surfaces, 30 percent for wearing surfaces	IS-2386 Part IV
3	Abrasion Value	27.4%	For aggregates to be used in concrete for wearing surfaces not exceed 30	IS-2386 Part IV
4	Impact Value	27.0%	shall not exceed 30 percent by weight for concrete for wearing surfaces	IS-2386 Part IV
5	Water Absorption 20mm & 10mm	1.62% (20mm) 1.80% (10mm)	-	IS-2386 Part III
6	Combined Elongation and Flakiness Indices	29.0%	Not to exceed 30%	% IS-2386 Part I

3.4 Silica Fume

Silica fume (Micro-silica) used in this study was procured from local chemical dealers confirming to IS 15388-2013.Physical and chemical properties of Micro-silica are given in Table -4 and Table -5 respectively.

Table -4: Physical properties of Micro-silica

Test	Result
Specific Gravity	2.15
Fineness (%)	--
Specific Surface Area (kg/m2)	496
Standard Consistency (%)	31
Initial Setting Time	120
Final Setting Time	300

Table -5: Chemical properties of silica fume

Test	Result %
Silica (SiO2)	95
Alumina Oxide (Al2O3)	1.12
Iron Oxide ((Fe2O3)	1.46
Ferric Oxide (Fe2O3)	1.3
Calcium Oxide (CaO)	0.2-0.8
Magnesium Oxide (MgO	
Sodium oxide (Na2O)	0.5-1.2
Potassium oxide (K2O)	
Loss on Ignition	Less than 0.6

3.5 GGBS

Ground Granulated Blast-furnace Slag (GGBS) used in this work is the mixed slag from JSW Granulated Slag used for JSW Steel Ltd., GBS conforms to **IS 12089:1987**.

Table -6: Physical & Mechanical Properties of GGBS

Test	GGBS
Colour	Off white
Consistency	33%
Fineness (sieving on 90μm)	0%
Fineness (Blain's air permeability)	320 m2 /kg
Specific gravity	2.88
Bulk density	1.29 gm/cm3

An X-Ray Fluorescence Machine was used to test the chemical properties of cement and GGBS at the J.Kumar Laboratory in BKC.

Table -7: Chemical Properties of GGBS

Chemical Composition	GGBS
CaO	35.27%
SiO2	34.72
Al2O3	19.11
MgO	8.46
Fe2O	0.5
SO3	0.18
Na2O	0.16
K2O	0.58
Cl	0.01
TiO2	0.65
P2O5	0.01
Mn2O3	0.14(MnO)
Glass Content	95

3.6 RAP Aggregates

3.6.1 Physical Properties of RAP

Some of the physical and mechanical properties of aggregates usually include Specific gravity, Water absorption, Bulk density, Abrasion Resistance, crushing strength and Impact resistance etc., these are the major properties which help in assessing the quality of the aggregates which are being used in the concrete mix.

The data provided in Table -8 was taken as an average by considering various available research data provided by different researchers. This data helps us to assess the quality of the RAP aggregates in comparison with the available natural aggregates.

Table -8: Physical and Mechanical properties of RAP.

S. No	PROPERTIES	COARSE RAP (20mm)	COARSE RAP (10mm)
1	Specific Gravity	2.2-2.6	2.2-2.6
2	Absorption (%)	1.8-2.9	1.8-2.8
3	Bulk density (Kg/m3)	1940-2300	1600-2200
4	Crushing value (%)	16-20	-
5	Impact value (%)	4.3-33	-
6	Abrasion resistance (%)	18-30	-

3.6.2 Chemical Properties OF RAP

RAP contains mineral aggregates of 93% to 97% by weight and 3% to 7% of hardened asphalt cement. In comparison to the chemical composition of natural aggregates, RAP has a similar composition.

Table -9 Chemical compositions of RAP aggregates

Element compound	Test result (% by weight)
SiO2	38
Fe2O3	26.8
CaO	16.3
Al2O3	11
SO3	2.9
TiO2	1.8
K2O	1.73
MnO	0.585
SrO	0.37
CuO	0.13
V2O5	0.11
BaO	0.2
Re2O7	0.06
ZrO2	0.055
ZnO	0.045

4. RESEARCH METHODOLOGY

Here, we will discuss the methodology used to achieve the main objectives of the study, as well as the materials used (Water, Cement, Natural fine & coarse aggregate, Micro-silica, GGBS, Admixture and RAP aggregates) used to be mixed in term to form the Recycled Asphalt Pavement (RAP) concrete to bring out the scopes and aims of this study. Concrete testing (Slump test, Compression strength test, Split Tensile strength test, Flexural strength Concrete test, Water Permeability test, Rapid Chloride Permeability Testing of concrete of Recycled Asphalt Pavement (RAP) were accomplished, and applied at Concrete Testing Laboratory (RMC Plant) in J. Kumar Infra projects Ltd. (Mumbai). The materials were used in this study are OPC – 53 Grade Cement, fine, and coarse aggregate, water, Micro-silica, GGBS, Admixtures and some % of Recycled Asphalt Pavement (RAP) as components of RAP concrete. There has been no standard mix design for Recycled Asphalt Pavement (RAP) concrete since this method is a new born method. The mix design was based on some trial mixing that was carried out 150 x 150 x 150mm cube test was used for determination of compressive strength.

4.1 Methods of Testing

After casting and compaction, the concrete specimens, it was kept in the laboratory for 24 hour. After that, they were de-moulded and cured in a fog room maintained at 20 ~ and 99% and placed in a curing tank, filled with water until testing for 7, 14 & 28 days. Then the specimens were removed from curing tank and tested immediately under Compression Testing Machine / Flexural Testing Machine.

4.1.1 Curing

Immediately after moulding the specimens, the cubes were stored in a place where it is free of any vibration and in an environment which prevents loss of moisture. The cubes were stored for 24 hours in room temperature to ensure a relative humidity of higher than 90%. After that, the specimens were released from moulds and were cured in water in a curing tank before testing. This curing process ensured the continuous hydration of the specimen by maintaining the temperature and moisture. The curing process followed the method of normal curing of test specimens (20 º C methods). Concrete properties improve with age as long as conditions were favourable to obtain the designed concrete strength.

Fig -1: Curing Concrete Cube

4.1.2 Slump test

The main purpose of slump test is to determine the degree of workability for concrete mix. The strength depends on how the concrete is being poured. Therefore, the concrete that is to be used must be easily poured and compacted. Factors that affect the workability are the water content, size and shape of aggregates and the water cement ratio. The cone for the slump test as specified IS: 1199-1959 has a height of 12 in, a bottom diameter of 8 inch and a top diameter of 4 inch. The slump test has been performed according to IS: 1199-1959

4.1.3 Compressive Strength Test

Depending on the size of the aggregate, either cubes of 15 cm x 15 cm x 15 cm or 10 cm x 10 cm x 10 cm are used for cube tests. It is common to use cubical molds of 15cm x 15cm x 15cm for most of the works. These specimens are tested by compression testing machine after 7, 14 days curing or 28 days of curing.

4.1.4 Flexural Strength Test

N/mm2 or MPa is the unit of measurement for concrete's flexural strength. The flexural strength of the concrete determined as per the IS 516-1959 standards. The casting of the beams are made with the shape of prism. In general, the beams are 150mm x 150mm x 700mm in size.

4.1.5 Split Tensile Test

Splitting tensile test is generally carried out to obtain the tensile strength of concrete, and the stress field in the tests is actually a biaxial stress field with compressive stress three times greater than the tensile stress. Split tensile strength tests were performed according to IS 5816-2004.

4.1.6 Rapid Chloride Permeability Test

Rapid Chloride Permeability Test Equipment (RCPT) is used to evaluate the resistance of concrete samples to the penetration of chloride ions. In the sample cells containing 3.0 % salt solution and 0.3 N sodium hydroxide solutions, a 100 mm diameter concrete cylinder is placed. Across the ends of the sample, a voltage of 60 V DC is maintained.

4.1.7 Water Permeability Test

It is particularly important to check the permeability of cement mortar or concrete in structures intended to retain or come into contact with water. Besides functional considerations, permeability is also intimately connected to the durability of concrete, especially its resistance to progressive deterioration in severe climates. Its resistance to leaching caused by prolonged seepage of water, particularly in the presence of aggressive gases or minerals.

4.2. Mix Design

Mix design for M40 grade of concrete was carried as per IS 456-2000. All the materials were proportioned by volume batching method. With proper dosage of Micro-silica, conventional concrete and concrete with recycled RAP aggregate content of 30%, 45 %, & 75% were cast. A slump cone test was conducted on the homogenous concrete mix.

Fig -2: Concrete Batching Apparatus

Table -10: Properties of different % replacement of RAP with Natural Aggregates

Sr. No	Characteristics	30% RAP (Mix 3)	45% RAP (Mix 2)	75% RAP (Mix 1)
1	Specific gravity	2.78	2.45	2.32
2	Water absorption	0.40%	0.48%	0.45%
3	Crushing Value	27.6%	28.2%	28.5%
4	Abrasion Value	28.0%	28.4%	28.7%
5	Impact Value	27.6%	28.3%	29.0%
6	Combined Elongation and Flakiness Index	28.9%	29.8%	30.0%

Based on these material properties, the Mix Design is prepared for Mix 1 (75% RAP), Mix 2 (45% RAP) and Mix 3 (30% RAP). The proportions and details of the mix are calculated using the IRC: 44-2008 method.

Table -11: Mix Details

Mix	NC	75% RAP (Mix 1)	45% RAP(Mix 2)	30% RAP(Mix 3)
W/C Ratio	0.35	0.35	0.35	0.35
Cement kg/cum	240	240	240	240
FA (Classified Sand) kg/cum	389	389	389	389

FA (C / SAND) kg/cum	391	391	391	391
CA 20MM	579	144.75	318.45	405.3
CA 10MM	431	107.75	237.05	301.7
RAP Kg/cum (20mm +10mm)	0.00	757.5	454.5	303
MICROSILICA	20	20	20	20
GGBS	240	240	240	240
Water kg/cum	175	175	175	175
Density of Concrete in kg/cum	2465	2299.79	2354.8	2383.06

The cube specimens were cast using 150 mm x 150 mm x 150 mm moulds for determining the compressive strength and water permeability test. Cylindrical specimens, 150 mm diameter x 300 mm height, were casted for split tensile strength test. Similarly prism specimens, 700 mm x 150 mm x 150 mm moulds for determining the Concrete flexural Beam strength test. The entire specimen were de-moulded after 24hrs and then subjected to water curing under room temperature. Enough specimens were cast to facilitate compressive strength tests at 7-days, 14-days, and 28-days as shown in Table -12.

Table -12: Number of Specimens Cast

Sr. No	Type of Concrete	Cubes	Beams	Cylinders
1	With 75% RAP (Mix 1)	15	9	6
2	With 45% RAP (Mix 2)	15	9	6
3	With 30% RAP (Mix 3)	15	9	6

Fig -3: Cube/Beam/Cylinder Specimens

5. RESULTS AND DISCUSSION

The following are the results of various tests such as the slump test, compression test, split tension test, flexural strength test, permeability test of concrete, and water penetration test of conventional concrete and concrete with recycled RAP aggregate content of 30%, 45 %, and 75% were cast with appropriate Micro-silica dosages.. The cubes were tested for 7, 14 and 28 days for each test.

Fig -4: Concrete filling in slump cone

Tests adopted for the measurement of the workability of the concrete mix in the present investigation are,

1. Slump Test

2. Compacting Factor Test.

The results of workability tests are tabulated in Table -13

Table -13: Measurement of Workability

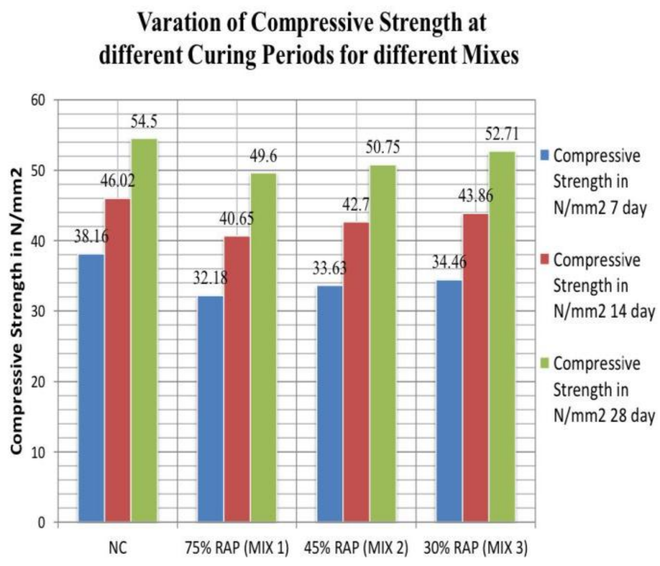
Sr. No	Name of the Test	75% RAP (Mix 1)	45% RAP (Mix 2)	30% RAP (Mix 3)
1	Slump cone Test (mm)	120	135	150
2	Compaction factor Test	0.82	0.85	0.88

5.1 Compressive Strength Test

The cube specimens were tested in Compression Testing Machine (CTM) after specified curing period for different % of RAP replacement 30%, 45% and 75%. Table -14 show the compressive strengths after the respective curing periods

Table -14: Compressive Strength Test Result for Replacement of RAP Aggregates %

Composition	Compressive Strength in N/mm²		
	7 days	14 Days	28 days
NC	38.16	46.02	54.50
75% RAP (MIX 1)	32.18	40.65	49.60
45% RAP (MIX 2)	33.63	42.70	50.75
30% RAP (MIX 3)	34.46	43.86	52.71



Graph -1: Showing Compressive Strength Development of Different Mixes

5.1.1 Discussion on Compressive Strength Results

Mix 3 is giving maximum strength of 96.71 % of NC strength, 52.71 N/mm2 which is very nearer to Normal Concrete Mix Strength for 28 days curing period. And also Mix 3 is showing good early strength of 34.46 N/mm2 for 7 day curing period, which is of 90.30% of strength gain with respect to NC Mix.

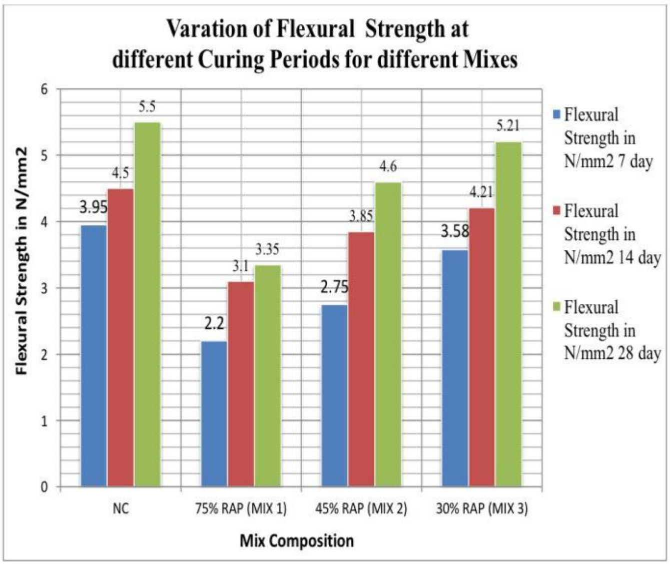
Fig -5: Cube under compressive testing machine

5.2 Flexural Strength Test

Test specimens were placed in a flexural testing machine and the flexural strength was calculated based on the failure plane position. Values obtained for concrete with different RAP replacement levels as note in Table -15 Concrete prisms (150X150X700mm) were used for the measurements of flexure strength in accordance with As per IS Code 516. A symmetrical two-point load was applied to the prisms (at the third point of the loaded span) the load was increased gradually with continuous monitoring of the mid-span deflection until failure.

Table -15: Flexural Strength Test Results for Replacement of RAP Aggregates %

Composition	Flexural Strength in N/mm²		
	7 days	14 days	28 days
NC	3.95	4.50	5.50
75% RAP (MIX 1)	2.2	3.1	3.35
45% RAP (MIX 2)	2.75	3.85	4.60
30% RAP (MIX 3)	3.58	4.21	5.21



Graph -2: Showing Flexural Strength Development of Different Mixes

5.2.1 Discussion on Flexural Strength Results

The results of flexural strength tests indicate that NC has higher flexural strength than different replacement levels of RAP. Mix 3 shows higher flexural strength of 5.21 N/mm2 for 28 days curing period, which is very nearer (94.72% of NC Strength) to strength of Normal Concrete (5.50 N/mm2)

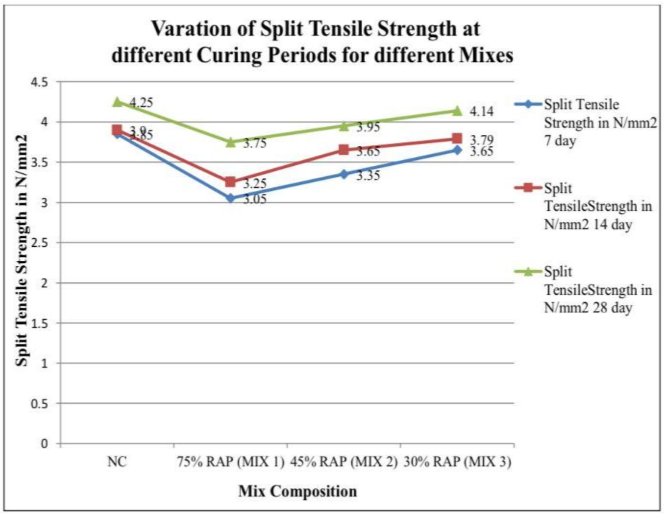
Fig -6: Placing Beam Specimen under Flexural Testing machine

5.3 Split Tensile Strength Test

Table -16 presents the results of split tensile strength tests conducted according to IS 5816-2004 for the various mixes after 7-days, 14-days, and 28-days of curing.

Table -16: Split Tensile Strength Test Results for Replacement of RAP Aggregates %

Composition	Split Tensile in N/mm²		
	7 days	14 days	28 days
NC	3.85	3.9	4.25
75% RAP (MIX 1)	3.05	3.25	3.75
45% RAP (MIX 2)	3.35	3.65	3.95
30% RAP (MIX 3)	3.65	3.79	4.14



Graph -3: Showing Split Tensile Strength Development of Different Mixes

5.3.1 Discussion on Split Tensile Strength Results

Not much has been studied on the effect of RAP on split tensile strength RAP different mixes; it is noted in the report that split tensile strength decreases as RAP content increases. Incorporating RAP reduces split tensile strength regardless of curing age. For instance, replacing 100% natural aggregates with combined RAP reduced the split tensile strength by about 38%, whereas incorporation of 45% combined RAP decreased the split tensile strength by about 14.57% only, which is why 45% combined RAP (20MM & 10MM) is recommended. Meanwhile, it was noticed only a 4.77% decrease in the split tensile strength, but only 30% of coarse RAP was utilized in this study.

From the test results of Split Tensile strength, it is observed that NC shows split tensile strength nearer to different RAP replacement levels. Mix 3 shows higher flexural strength of 4.41 N/mm2 for 28 days curing period, which is very nearer (97.411% of NC Strength) to strength of Normal Concrete (4.25 N/mm2).

Fig -7: Split Tensile Testing Machine

5.4 Rapid Chloride Permeability Test (RCPT)

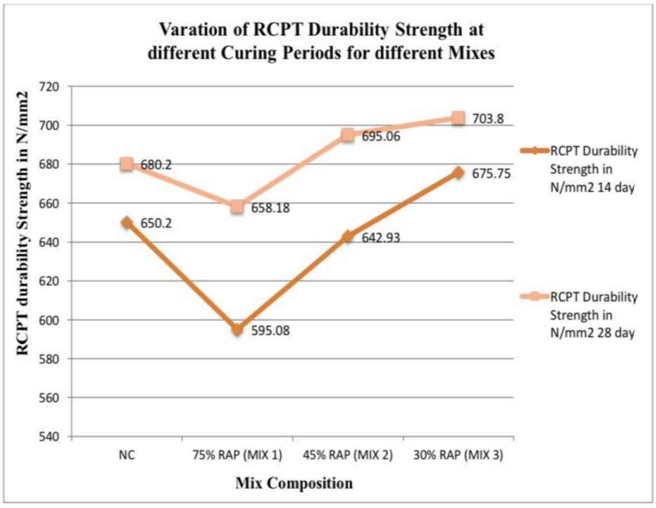
The Rapid Chloride Permeability Test (RCPT) determines how easily chloride ions can penetrate. Rapid chloride permeability tests RCPT-ASTM C-1202 are commonly used to assess concrete's resistance to chloride ion ingress since they are simple and quick.

Table -17: Rapid Chloride permeability test Results for Replacement of RAP Aggregates %

Composition	Rapid Chloride Permeability in Coulombs	
	14 days	28 days
NC	650.20	680.20
75% RAP (MIX 1)	595.08	658.18
45% RAP (MIX 2)	642.93	695.06
30% RAP (MIX 3)	675.75	703.80

5.4.1 Discussion on RCPT (Durability) Strength Results

The results of RCPT tests of all three mixes at different curing periods are presented in **Graph -4.** it is seen that the RCPT value increases for 30% RAP mixes as compared to NC due to rise in Micro-silica contents up to 3.46 % for all the curing periods. At higher levels of Micro-silica above 3.46 % as a replacement for OPC-53 Grade, the values are found to increase. The initial improvement in resistance to chloride ion penetration is credited to the mix's densification as a result of the addition of finer Silica fume particles than OPC particles to fill in voids. Further, with an increased curing period the RCPT values are found to increase in RAP mixes for 28days as compared to normal mix.



Graph -4: Showing RCPT Durability Strength test Development of Different Mixes

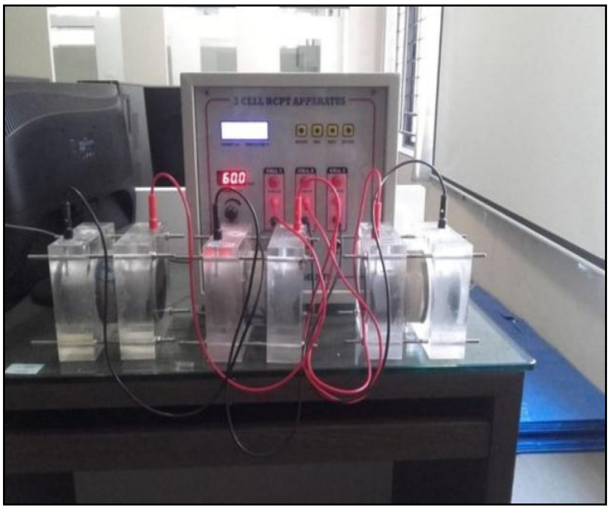


Fig -8: RCPT Testing Machine

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the experiments, and based on the results, and the analysis of this study, the following conclusions were made:

- Workability of concrete containing RAP aggregate is significantly decreased because of high porosity and low density of RAP aggregate requires a large amount of water to achieve the required slump.

- Irrespective of the curing period of RAP aggregate concrete, an increase in the percentage of RAP aggregate diminishes compressive, tensile and flexural strength. However, addition of silica fume enhances the performance of RAP aggregate concrete.

• When compressive strength analysis of RAP inclusive concrete has been made, it was determined that the strength of the specimens decreases with an increment in the RAP aggregates this was due to the weak bond between the asphalt film around the RAP aggregate and the cement paste. But as a solution to this, treated RAP aggregates which are free from dirt has a better performance. Replacement of 30% RAP (Mix-3) gives maximum compressive strength comparatively than other replacement percentages (About 96.71% of NC Strength).

•The flexure and split tensile strengths of the concrete specimens using RAP aggregates followed the same pattern as the compressive strength, and they both increased in accordance with it. But it was assessed that due to the presence of the asphalt film around the RAP aggregates, the load absorption of the concrete specimens increased in comparison with the concrete made of natural aggregates. This resulted from the concrete's elastic modulus being decreased while its RAP content was increased. In comparison to the RAP-replaced mixes, the reference mix exhibits greater maximum flexural strength. But the Mix-3, i.e. Strength is coming extremely close to that of NC with a 30% RAP replacement.

Because RAP has a higher permeability than regular concrete, using it increases the risk of reinforcing corrosion. This was brought on by the gradation and fineness modulus of the RAP aggregates. When using RAP aggregates, this issue can be resolved by using silica fume to increase the permeability of the concrete.

• When recycled aggregate is used in place of natural aggregate with 3.50% silica fume, the results are comparable to control mix.

• The following arguments are made in favour of the usage of RAP Mix:

A. Flexible pavement that is simple to remove; use of its material in the construction of concrete pavement. As a result, the price of transportation and natural aggregates is decreased.

B. Using RAP aggregate also lessens the need for natural course aggregate, which is increasing due to the construction of new roads.

C. Removing natural material from a quarry contributes to reducing pollution and environmental imbalances.

6.2 Recommendations

Recycled Asphalt Pavement (RAP) concrete is sustainable technology, and it is helpful and useful to be used in construction sites, that regarding to it is advantages and benefits, as it is less costly, and reduce the usage of natural aggregate recourses. Some of the recommendations have been recorded in the following lines:

1. Proper techniques should be used for obtaining, stockpiling, and processing RAP to maintain its quality. In the case of high RAP mixtures, fractionation of the RAP material may be necessary

2. To try different lower partial replacement percentages of RAP as coarse aggregate in concrete to compare its results with the results of this study.

3. To try partial replacement of RAP as fine aggregate in concrete.

4. It is also recommended not to use concrete containing RAP aggregate in construction site, that because the lowest strength that have been recorded. And use it for non-structural applications. Such as walkways or playgrounds.

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