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UTILIZATION OF BITUMINIOUS PAVEMENT WASTE AS REPLACEMENT MATERIAL IN CEMENT CONCRETE

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ABSTRACT: In general, aggregate make up 60-75% of concrete volume, so their selection is important, also they control concrete properties. Aggregate provide strength and wear resistance in these applications. Hence, the selection and proportioning of aggregate should be given careful attention. The aggregate is generally coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand or stone dust. Bulk of pavement structure is formed by aggregate. This paper presents a review on the use of bituminous pavement wastes in cement concrete. This will help in achieving economy in building and road construction as well as saving environmental degradation in term of reduced mining and less pollution. In present study I use recycled pavement waste in concrete grade of M35 with varying percentage like 25, 50, 75 and 100 %.

I. INTRODUCTION

Concrete is a composite construction material composed primarily of aggregate, cement and water, In general, aggregate make up 60%-75% of total concrete volume, so their selection is important, also they control concrete properties, Aggregate provide bulk, strength and wear resistance in these application. Hence, the selection and proportioning of aggregate should be given careful attention. The aggregate is generally coarse gravel or crushed rocks such as limestone, or granite, along with a fine aggregate such as sand or stone dust. Bulk of pavement structure is formed by aggregate. The major function of the pavement is to transfer wheel load to the sub grade. In this load transfer mechanism aggregates have to bear stresses occurring due to wheel loads on the pavement and on the surface course, they also have to resist wear due to abrasive action of traffic. Therefore the properties of aggregate are of considerable significance to the highway engineers. The aggregate are categorized based on their size, shape, texture and gradation. The aggregate serves as reinforcement to add Strength to the overall composite material. Aggregates are also used as base material under foundations, roads, and railroads. Recycled asphalt pavement (RAP) is the removed and reprocessed pavement material containing asphalt and aggregate. The use of recycled asphalt pavement has become a common practice in the construction of new and reconstruction of new, and reconstruction of old, hot mix asphalt pavements. But little research has been done to examine to potential of incorporating RAP into cement concrete. In the present study, the physical and mechanical properties of cement concrete comprising of RAP, in different proportions, are investigated through laboratory experiments. Recycled asphalt pavement used in the present study is obtained from the debris of dismantled asphalt road.

Obtaining Recycled Asphalt Pavement

Asphalt pavement is generally removed either by milling or full-depth removal.Milling involves the removal of the pavement surface using a milling machine, which can remove up to 2 inch (50 mm) thickness in a single pass. Full-depth removal involves ripping and breaking the pavement using a rhino born on bulldozer and involves pneumatic pavement breakers. In most instances, the broken material is picked up by front-end loaders and loaded into haul trucks. The material is then hauled to a central facility for processing. At this futility, the RAP is processed using a series of operations, including crushing, screening, conveying, and stacking.

Two processes which are essential for carrying out recycling of existing asphalt pavements are:

- Cold milling of existing road and
- HOT mix asphalt plant.

Above two are discussed briefly given following section

Cold Milling

The method of removing asphalt pavement to a desired depth and then it's restoration of the surface to a desired grade and slope is called cold milling. It gives surface freeof humps, ruts and other distresses. This method can also be used for the roughening or texturing of a pavement to improve frictional resistance. Whole process is done using a self-propelled rotary drum. The rotary drum is fitted with tungsten carbide teeth, which can bite through hard rock particles. The resulting pavement can be used immediately or overlaid at some future time or left as a textured surface.

2.3.2 Hot Mix Asphalt Plant

Hot recycling or hot mix recycling (Figure 2.2) is the process in which reclaimed asphalt pavement (RAP) material is combined with new materials (asphalt binder and aggregate) to produce hot mix asphalt (RMA) mixtures. Both batch and drum type hot mix plants are used to produce recycled mix. The RAP material can be obtained by milling or ripping and crushing operation

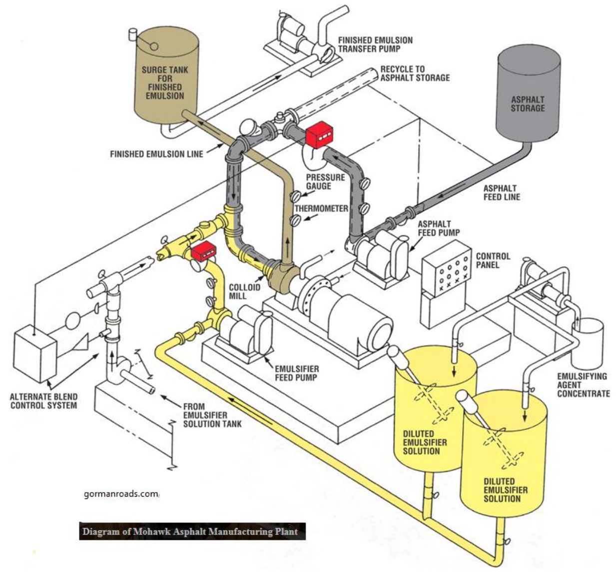

Fig. Hot Mix Plant

Concrete Kerb and Gutter Mix

Recycled aggregate have been used as concrete kerb and gutter mix in Australia. There is proper use of l0mm recycled aggregate and blended recycled sand for concrete kerb and gutter mix in the Lenthall Street project in Sydney

Figure Recycled Aggregate as Road Kerb

II. OBJECTIVE

The primary goal of this project is to develop and characterize an environment friendly concrete suitable for transportation-related applications. The objectives of the study include:

- To study the various properties of selected material like specific gravity, water absorption, crushing value, impact value and gradation to determine the suitability for high strength concrete.
- Preparation ofMix Design of M35 Grade Cement Concrete.
- Check for compressive strength of M35 Grade Cement Concrete.
- Comparison study between the followings:
  - RAP aggregate and Fresh coarse aggregate
  - Fresh aggregate concrete and Recycled asphalt pavement concrete

III. SCOPE

In this project, the mix design of M35 Grade of cement concrete is developed at water cement ratio 0.45 using virgin coarse aggregate (CA). In order to study the potential of RAP in the mix design of M35 grade cement concrete, different percentage of RAP aggregate are used in mix with coarse aggregate and their corresponding compressive and flexural strength are studied. A total of five batches are considered in which the percentage of RAP and fresh coarse aggregate are as follows:

1. 0% RAP and 100%CA
2. 25% RAP and 75% CA
3. 50% RAP and 50% CA
4. 75% RAP and 25% CA
5. 100% and 0% CA

Water cement ratio in total of five batches of concrete mix has kept constant as 0.45.

IV. MATERIALS USED AND METHODOLOGY OF THE STUDY

Methodology of the study for the present research work describe the procurement of the material and to carry out different test as per IS codes

Material used

The materials used in the test program include--

1. Portland pozzolonic cement (ultratech cement).
2. Natural coarse aggregate.
3. Recycled asphalt pavement aggregate.
4. Sand and water.

1. Cement: Portland pozzolonic cement conforming to IS 1489(part 2):1991 is used in test program which specific gravity is: 3.15 (ultratech cement).
2. Water: Tap water, potable free from salts or chemical is used in test program.
3. Natural Aggregate: Two grades of coarse aggregate i.e. 20mm and 10 mm are used in the present study. Aggregates procured are from nearby construction area.
4. Fine aggregate (Sand):Jehlum river bed sand, used in the study, is obtained from Anantnag market.
5. Recycled Asphalt Pavement (RAP): Recycled asphalt pavement is reclaimed and processed pavement material containing asphalt and aggregate. RAP is a waste material and is economical available as compare to fresh aggregate. Size of recycled asphalt pavement used in testing program lies between 20mm to 4.75mm. It is collected from Kulgam District Roads.

3.3 Testing Program

A series of test were conducted on fresh aggregate and recycled asphalt pavement,

3.3.1 Test on Fresh Coarse Aggregate

(1) Sieve Analysis
(2) Specific gravity
(3) Water absorption
(4) Aggregate crushing value
(5) Aggregate impact value

Test on Recycled Asphalt Pavement

(1) Sieve Analysis
(2) Specific gravity
(3) Water absorption

Test on Recycled Asphalt Pavement

(1) Sieve Analysis

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(2) Specific gravity
(3) Water absorption
(4) Aggregate crushing value
(5) Aggregate impact value
(6) Bitumen content

Test on Fine Aggregate
(1) Sieve Analysis
(2) Specific gravity
(3) Water absorption

Detail Testing Program
Specific Gravity
Theory
The specific gravity of an aggregate (G) is defined as the ratio of the mass of a given volume of solids (Ms) to the mass of an equal volume of water (Mw) at 4 °C. Therefore
G =Ms / Mw
Since the aggregate generally contains voids therefore there are different types of specific gravity.
Water absorption
The water absorption of an aggregate is defined as the ratio of weight of water absorbed by sample when immersed in water for 24 hours to the weight of an oven dry absorbed by sample. The water absorption of an aggregate play an important role in design mix grade concrete. It affects the workability and final volume concrete in the mix design. Relationship used for calculation of water absorption is as follows
Wx= (Wy-Ws) Ws x 100
Where Wx denote the water absorption of an aggregate (percent of dry weight).
Wy denote the weight of the aggregate after aggregate is immersed
in water for 24 hour
Ws denote the weight of the aggregate after the aggregate is placed in oven
Dry for 2 hour at temperature 100± 50 C.
Test procedure of Specific Gravity and Water absorption of Coarse Aggregate
The specific gravity and water absorption of coarse aggregate is determined byfollowing the procedure giving in IS: 2386 (part iii) – 1963, page :-4) The Procedure used todetermine the specific gravity and water absorption are as follows.
Apparatus required - The apparatus shall consist of the following:
1. Balance – The balance shall be of sufficient capacity and sensitivity and shall have an accuracy of 0.1 percent of the weight of the test sample
2. Oven – A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110.c
3. A wire basket of not more than 6.3 mm mesh or perforated container of convenient size.
4.A watertight container in which the wire basket may be freely suspended from the balance as shown in Figure
5.Two dry soft absorbent cloths each not less than 75×45 cm.
6.A shallow tray of area not less than 650cm

Figure Water Absorption Test Machine

Test Procedure
Take sample and weighed it by balance. After this the weight of sample is taken in water and then it is allowed to remain complete immersed in water for a period of 2 hours. Whole operation is carried out by the wire basked I which the sample is placed and allowed to freely suspend in the watertight container from the balance as shown in Figure 3.1 Afterwards. The sample is taking out from water and then wiped by dry cloths and then weighed t At last, the weight of sample is taken after it is placed in over dry for a period of 2 hours at temperature 100 to 110.c Calculation procedure of the specific gravity and water absorption of coarse aggregate are as follows.
Calculation
Total weight of sample has taken = A kg
The weight of sample in water = B kg
The weight of sample, after it is taking out from water, in which sample is immersed for 24 hours and then wiped by dry cloth = C kg
The weight of the sample, after the sample is placed in oven dry for a period of 2 hours at
temperature 100 to 110^0 = D kg.
Specific gravity = D/ (C-B)
Apparent specific gravity = D(D-B)
Water Absorption percent of dry weight =(C-D)/D×100
Test Procedure of Specific Gravity and Water Absorption of Fine Aggregate
The specific gravity and water absorption of fine aggregate is determined by following the procedure giving in is 2386 (part iii) – 1963, Page-8).The procedure used to determine the specific gravity and water absorption are as follows.
Apparatus required – The apparatus shall consist of the following.
1. Balance – The balance shall be of sufficient capacity and sensitivity and shall have an accuracy of 0.1 percent of the weight of the test sample.
2.Oven – A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110.c
3. Vessel – Any form of vessel capable of holding 0.5 to 1 kg of material up to 10mm in size and capable of being filled with water to a constant volume and accuracy of 0.5 ml.
4. A Pycnometer bottle of about one litre capacity having a metal conical screw top with a 6mm diameter hole at its apex is uses is show in Figure 3.2
5 A tray of area not less than 325 cm^2

Figure Pycnometer Bottle

Test Procedure

A sample of about 0.5kg is taken in the pycnometer. The weight of pycnometer containing dry sample is taken by balanced. Water is added in the sample to fll about half to three fourth of the pycnometer. Soak the sample for 10 minutes so that the entrapped air can remove. Then more water is added to the sample till to pycnometer is filled lush, with the hole in the conical cap. The pycnometer is wiped by dry cloth is filled flush, with the hole in the conical cap. The pyrometer is wiped by dry cloth and weighed. It Then empty the pycnometer and clean it. The wet sample is placed in an over dry for a period of 2 hours at a temperature 105±50C after this is weighed. A last, the pycnometer is filled with water only, flushes with the top hole and weighed it. Calculation procedure of the specific gravity and water absorption of fine aggregate are as follows.

Calculation

Weight of the sample = A kg

Wight of pycnometer containing sample and filled with water = B kg.

Weight of pycnometer filled with water only =C kg

Weight of oven dried sample = D kg

Specific gravity = D/(A-(B-C))

Apparent specific gravity = D/(D-(B-C))

Water absorption (percent of dry weight) =(A-D)/ D× 100

Aggregate impact Value

Theory

Aggregate used in pavement are also subjected to impact due to moving traffic load. The steel wheels of moving vehicles when jumped from one particle to another at different levels, causes severe impact on aggregate. Thus it also affects the service life of pavement. The test which is conducted on aggregates against this impact load toughness is known as Impact strengthtest the test result gives the strength of aggregate in term of aggregate impact value The aggregate impact value means, the resistance of aggregate to sudden shock or impact i.e toughness

The impact strength test of coarse aggregate is determined by following the procedure giving in is 2386 part 4 1963 page - 10 The procedure uses to determine the impact strength of aggregate are as follows.

Apparatus required – The apparatus shall consist of the following:

1 Impact testing machine as shown in Figure 3.4

2. A balance of capacity 3kg, readable and accurate to one gram.

3. IS a sieve of sizes 12.5 mm, 10 mm and 2.36 mm

4. A straight metal tamping rod of circular cross – section 1 mm in diameter and 230 mm long,

5. A cylindrical steel cup of internal dimensions:

Diameter - 102.mm

Depth-50 mm

Test Procedure

Aggregate specimen passing 12.5 m sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal diameter 102.mm and depth 5 mmin 3 layers. Each layer is tampered 25 times with the tamping rod. The cylindrical steel cup filled with specimen in then attached to a metal base of impact testing machine as shown in Figure 3.4 The hammer of weight 13.5 to 14 kg is raise to height of 38 cm above the upper surface of the specimen and is allowed to fall freely on the specimen The test specimen is subject to 15 bolos Then the crushed aggregates are then sieved through 2.6mm sieve and weight of passing material is expressed as percentage of the weight of the total sample which is the aggregate impact value.

Calculation

Weight of the sample= A kg

Weight of the sample retained on IS sieve 2.36 mm, after hammering the sample by 15 blows = Bkg

Weight of fraction passing the appropriate is sieve 2.36 mm (C)= A-B

Aggregate impact value (Percent of dry weight) = C/A × 100

Figure Aggregate Impact Test Machine

Bitumen content test

Theory

The test which is used to determine the asphalt content of asphalt aggregate is known as bitumen content test.

The bitumen content testis carried out by following the procedure as per ASTM 2172

Apparatus required- The apparatus shall consist to the following

1 Centrifuge extractor as shown in Figure 3.5

2 Miscellaneous – bowl, filter paper, balance, and commercial benzene.

3 A sample of 200 gm is taken.

Test procedure

A sample of 200gm is taken and then spread in the bowl of the centrifuge extractor. The sample is covered by benzene

and then put the filter paper ion it centrifuge extractor. The sample is covered by benzene and then put the filter paper on it After this, the cover plate is fitted on the bowl tightly as shown in Figure 3.5 start the centrifuge extractor, revolving slowly and gradually
increase the speed up to 3600 rpm until the solvent ceases to flow from the outlet .Allow the centrifuge extractor to stop. Remove the cooer plate and filter paper from the bowl and then take out the sample from centrifuge extractor and then weight it. Calculation procedure of the bitumen content test is as follows.

Calculation

Weight of the sample(RAP) place in centrifuge extractor = A gm.

Weight of the extracted sample (RAP) (B) = B gm.

Bitumen content (percent of extracted sample) = (A-B)/Bx100

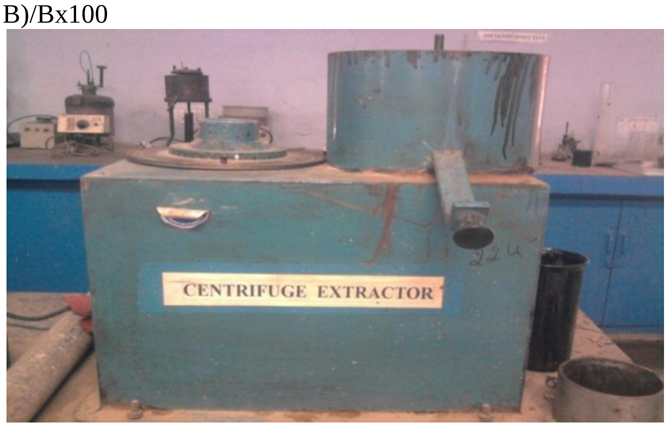

Figure Centrifuge Extractor

Grading Limits for coarse Aggregate As per IS:383-1970

IS Sieve	Percentage passing for single sized aggregate for nominal size						% passing for graded aggregate of nominal size		
	63mm	40mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16mm
1	2	3	4	5	6	7	8	9	10
80	100	-	-	-	-	-	100	-	-
63	85 to100	100	-	-	-	-	-	-	-
40	0 to30	85/00	100	-	-	-	95 to 100	100	-
20	0to5	0to20	85 to100	100	-	-	-3 to70	95TO100	100
16	-	-	-	-	-	-	-	-	90-100
12.5	-	-	-	-	85 -100	100	-	-	90-100
10	0 to 5	0 to 5	0 to 20	0 to 30	0 to 45	85 to 100	10 to 35	25 to 55	30 to 70
4.75	-	-	0to 5	0 to 5	0to 10	0 to 20	0 to5	0to 10	0to 10
2.36	-	-	-	-	-	0 to 5	-	-	-

It is also necessary to determine the grading zone on which the fine aggregate islaid. So therefore, the grading of fine aggregate is required. There are four grading zone, specified by IS : 383- 1970 code and IRC 44-2008. They are calledby grading zone I, grading zone 2, grading zone 3 and grading zone 4. According IRC 44-2008 (Table 6), the volume of coarse aggregate per unit total volume of total aggregate for different zone of fine aggregate is different zone of time aggregate is different. So therefore the grading of fine aggregate is also play animportant role in the mix design. Table 3.2 shows the grading limits for fineaggregate.

Table Grading Limits for Fine Aggregate As Per IS: 383-1970

IS sieve Designation (mm)	Percentage passing for			
	Percentage Grading zone 1	Passing Grading zone 2	For Grading zone 3	Grading zone 4
10	100	100	100	
4.75	90-100	90-100	90-100	95-100
2.36	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-90	90-100
.6	15-34	35-59	60-79	80-100
.3	5-20	8-30	12-40	15-50
.15	0-10	0-10	0-10	0-15

Mix Design of M35 Grade Cement Concrete

The design procedure as per is code and IRC 44.2008 is used in mix design of M35 grade cement concrete. The material required in the design of M35 grade concrete is as per calculation.

Method for concrete mix design:-

The various methods used for concrete mix design are:-

ISI mix design method

Trial and error method

USBR Mix Design method

Minimum Void method

Maximum density method

Fineness modulus method

British mix design method

ACI mix design method

In present study mix design was done by ISI mix design method.

ISI mix design method

The basic steps involved in the concrete mix design can be summarized as follows:-

- Based on the level of quality control the mean target strength is estimated from the specified characteristic strength.
- The water cement ratio is selected for the mean target strength and checked for the requirements of durability.
- The water content for the required workability is determined.
- The cement content can be determined from the water cement ratio and water content obtained in step (ii) and (iii) respectively and is checked for the water requirements.
- The relative proportion of fine and coarse aggregates is selected from the characteristic of

coarse and fine aggregate.

- The trial mix proportions are determined.
- The trial mixes are tested for verifying the compressive strength and suitable adjustments are made to arrive at the final mix composition.

Types of Mixes

a) Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

b) Standard mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

c) Designed Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm2. No control testing is necessary reliance being placed on the masses of the ingredients.

d) Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate.

IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

e) Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

f) Quality Control

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

Factors to be considered for mix design

- The grade designation giving the characteristic strength requirement of concrete.
- The type of cement influences the rate of development of compressive strength of concrete.
- Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
- The cement content is to be limited from shrinkage, cracking and creep.
- The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

Target mean strength for mix proportioning

In order that not more than specified proportion of test results are likely to fall below the characteristics strength, the concrete mix has to be proportioned for higher target mean compressive strength $f'_{ck.}$ The margin over characteristic strength is given by the following relation

$f'_{ck} = f_{ck} + K\sigma$

where

f'_{ck} = target mean compressive strength at 28 days in N/mm^2

f_{ck} = characteristic compressive strength at 28 days in N/mm^2

K = Himsworth Coefficient is taken as 1.65 for 5 % probability of failure.

σ = Standard deviation N/mm^2

The values of σ are given in Table 1 of IS 10262-2009 for fair, good and very good degree of control

Say for M35 grade of concrete,

K = 1.65 (where 5% result are allowed to fall below specific design strength)

Standard Deviation= 5 N / mm².

Target Mean Strength = 35 + 1.65 × 5 = 43.25 N/mm²

Selection of water cement ratio

From table 5 of IS 456-2000, maximum water cement ratio is 0.45.

Selection of water content

From Table 2 of IS 10262-2009, maximum water content is 186 litre for (25 to50mm slump range) for 20mm aggregate

Estimated water content for 75mm slump = 186+ $\frac{3}{100}\times 186$
= 191.58
Calculation of cement content
Water –cement ratio = 0.45
Cement content = $\frac{191.58}{0.45}$ = 425 kg/m^3
Proportion of volume of coarse aggregate and fine aggregate
From Table 3 of IS 10262-2009 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate(zone 2) for water cement ratio of 0.50 = 0.62
In this case water cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water cement ratio is lower by 0.05, the proportion of coarse aggregate is increased by 0.01(at the rate of ±0.01for every ±0.05 change in water cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water
cement ratio of 0.45=0.63
Mix calculation
The mix calculations per unit volume of concrete shall be as follows:
Volume of concrete(a) = 1 m^3
Volume of cement(b) = $\frac{\text{Mass of cement}}{\text{specific gravity of cement}}\times\frac{1}{1000}$
$= \frac{425}{3.15}\times\frac{1}{1000}$
= 0.134m^3
Volume of water(c) = $\frac{\text{Mass of water}}{\text{specific gravity of water}}\times\frac{1}{1000}$
$= \frac{191.58}{1}\times\frac{1}{1000}$
= 0.19158
Volume of all in aggregate(d) $= [a - (b + c)]$
= 1- 0.325
= 0.675 m^3

Mass of coarse aggregate = d × volume of coarse aggregate × specific
gravity of coarse aggregate × 1000
= 0.675 × 0.63 × 2.75 × 1000
= 1169.43 kg

Mass of fine aggregate = d × volume of fine aggregate × specific
gravity of fine aggregate × 1000
= 0.675 × 0.37 × 2.66 × 1000
= 664.33kg

Table: Mix Quantities Used per cubic meter of Concrete

Mixture no.	Cement kg/m^3	Fine aggregate kg/m^3	Coarse aggregate kg/m^3		Water lit/m^3
			Fresh Aggregate (kg)	Recycled Aggregate (kg)	
1	425	664.33	1169.43	0	191.58
2	425	664.33	877.07	292.35	191.58
3	425	664.33	584.71	584.71	191.58
4	425	664.33	292.35	877.07	191.58
5	425	664.33	0	1169.43	191.58

V. TEST RESULTS AND DISCUSSION

A series of tests are conducted in the laboratory for evaluation of various properties ofmaterial, relevant for the study. All test have been conducted as per the guidelines of IS codes recommendation. Test results are summarizedin tabular form.

Specific Gravity and Water Absorption Test of Coarse Aggregate

Measure of quality or strength of a material is defined by its specific gravity. Aggregate having low specific gravity values are generally weaker than those having higher values. It is a dimensionless value and also used determine thevolume of aggregate in concrete mixes. The specific gravity of coarse aggregateand RAP aggregate are determined, according to Is codes: 2386 (part iii)-1983.Result is shown in table 4.1.

The water absorption of aggregate is percentage of water present in a sample ofWater percent in a sample of aggregate either inside pores or on the surface.Absorption value is porous and thus weak. The water absorption of coarse Aggregate and RAP aggregate are determined by the above mention procedure(IS codes: 2386 (part iii) – Result is shown in Table 4.1. calculation for specificGravity and water absorption on coarse aggregate of 10mm size is as follows and the same procedure is used to determine specific gravity and water absorption for RAP aggregate and coarse aggregate of 20mm.

Calculation

Total weight of coarse aggregate (10mm) has taken (A) = 1 kg

The weight of coarse aggregate in water (B) = 0.620 kg

The weight of coarse aggregate, after the coarse aggregate is immersed in water for a period of 24 hours and then wiped by dry cloths (C) = 1.010kg

The weight of coarse aggregate, after the coarse aggregate is placed in oven dry for a period of 2 hours at a temperature 100 to 110. C (D) = 0.994 kg

Specific gravity = D/C-B
= (0.994/ (1.010-0.620)) = 2.548=2.55

Water absorption (percent of dry weight) = (C-D)/D x 100
= ((1.010-0.994)/ 0.994)x 100= 1.61%

Table: Result of Specific Gravity and Water and Water Absorption Test on coarse Aggregate and Rap (Size B/W 20mm to 4.75 mm)

Sample	10 mm	20 mm	RAP
Weight of the aggregate	1 Kg	1Kg	1 Kg
Weight of the aggregate in water	0.620 kg	0.625 kg	0.952 kg
The weight of the aggregate in air after the aggregate is immersed in water for a period of 24 hours and then wiped by dry cloth	1.010 kg	1.100 kg	0.952 kg
The weight of the aggregate after, the aggregate is placed			

in oven dry for a period of 2 hours at temperature 100 to 110. C	0.994kg	1.001 kg	0.940 kg
Specific gravity	2.55	2.36	2.556
Water absorption (percent of dry weight)	1.61 %	1.63 %	1.2%

Specific Gravity and Water Absorption Test of Fine Aggregate (Sand)

Specific Gravity and Water absorption of Fine aggregate (sand) is determined by pycnometer method describe in IS: 2386 (part iii)- 1963, page:- 8, Results are shown in Table – 4.2

Calculation

Weight of sand (A) = 0.5 kg

Weight of pycnometer of gas jar containing sand and filled with water (B) = 1.832 Kg

Weight of pycnometer or gas jar filled with water only (C) = 1.513 kg

Weight of oven dried sand (D) = 0.488 kg

Specific gravity = D/A – (B-C)

= (0.495/ (0.5-(0.495-(1.832-1.832-1.513))) = 2.55

Water absorption (percent of dry weight = (A-D)/D x 100

= ((0.5-0.495)/0.495) x100 = 1.13%

Table: Result Specific Gravity and Water Absorption Test on Fine Aggregate

Weight of sand	0.5 kg
Weight of pycnometer or gas jar containing sand and filled with water	1.832 kg
Weigh of pycnometer or gas jar filled with Water only	1.513 kg
Weigh of oven dried sand	0.495 kg
Specific gravity	2.55 kg
Water absorption (percent of dry weight)	1.13%

Aggregate Impact Test

Aggregate in the pavements are subject to impact due to moving wheel loads. Therefore it should have sufficient strength against impact The test which is designed to evaluate toughness of stone or resistance of the aggregates to fracture under repeated impacts is called impact test the impact value gives a relative measure of the resistance of an aggregate to sudden shock or an impact. It has a different effect than the resistance to compressive force. Aggregate impact value of coarse aggregate and RAP aggregate are determined by following the procedure giving in IS codes: 2386 (part 4)-1983 Result are shown in Table 4.3. Calculation forImpact value on coarse aggregate of 20mm size is as follows and the same procedure isused to determine the impact value for RAP aggregate.

Calculation

Weight of coarse aggregate (A) = 0.370 kg

Weight of coarse aggregate retained on IS sieve 2.36 mm after hammering the sample
by 15 blows (B) =0.330 kg

Weight of the coarse aggregate fraction passing the appropriate IS
sieve 2.36 mm (C) = A – B
= (0.370-0.330) = 0.040 kg

Aggregate impact value (percent of dry weight) = C/A x 100
= (0.040/0.370) x 100 = 10.81%

Table: Result of Aggregate Impact Value Test on Coarse Aggregate (20mm) and RAP

Sample	Coarse aggregate (20mm)	RAP
Weight of the aggregate	0.370 kg	0.340 kg
Weight of the aggregate retained on sieve 2.36 mm after hammering the sample by 15 blows	0.30 kg	0.286 kg
Weight of the aggregate fraction passing the appropriate IS sieve 2.36 mm	0.040 kg	0.050 kg
Aggregate impact value(Percent of dry weight)	10.81%	15.29%

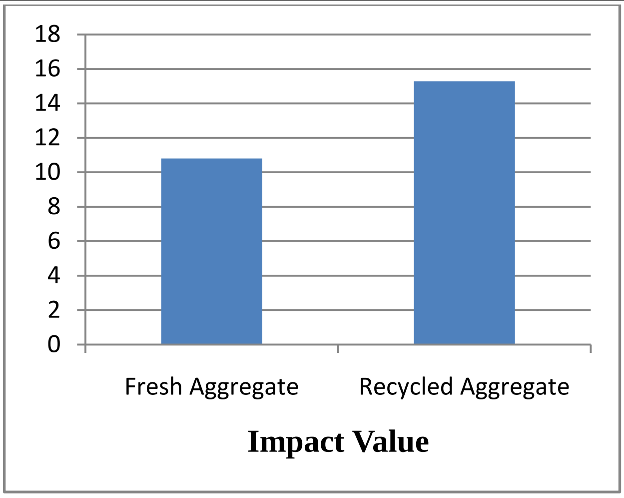

Fig. Impact Value Test

Crushing Strength Test

Due to traffic wheel load, the aggregate uses in road construction should be sufficiently strong to withstand the compressive stresses felt on it. This mainly applies to aggregate uses in top layer. The aggregate should be capable of withstanding high stresses in addition to wear and tear So therefore, it possess sufficiently strength against crushing The test which as designed to evaluate the strength of aggregate against crushing is known as crushing strength test. Crushing value gives a relative measure of the resistance of an aggregate to crushing under agradually applied compressive load, Aggregate crushing value of coarse aggregate and RAP aggregate are determine by following the procedure giving is IS codes: 2386 {art 1983. Results are shown in Table 4.4 Calculation for crushing value on coarse aggregate of 20 mm size in as follows and the same procedure is uses to determine the cashing value for RAP aggregate.

Calculation

Weight of coarse aggregate (A)=2.720 kg

Weight of coarse aggregates retain on IS sieve 2.36 mm after place in compression testing machine (B)=2.255 kg

Weight of coarse aggregate fraction passing the appropriate is sieve 2.36 mm (C) =(A-B)
=(2.720-2.255)=0.465

Aggregate crushing value (percent of dry weight) = C/A x100=0.465/2.720)x100 =17.09%

Table Result of Aggregate Crushing Value Test on Coarse Aggregate (20mm) and RAP

Sample	Coarse Aggregate	RAP
Weight of the aggregate	2.720 kg	2.434 kg
Weight of the aggregates ration on IS sieve 2.36 mm after place In compression testing machine	2.255 kg	2.094kg
Weight of the aggregate fraction asking the appropriate is sieve 2.36 mm	0.465k g	0.42 kg
Aggregate crushing value (percent of dry weight)	17.09%	17.28

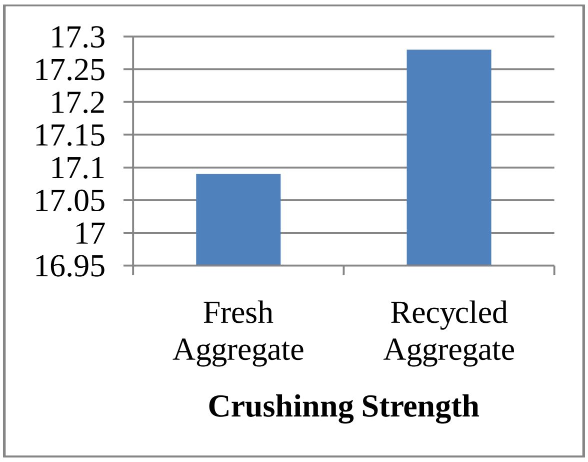

Fig. Crushing strength Test

Bitumen Content

This test is carried out and determines the bitumen content in RAP as per ASTM 2172.Results are shown in Table 4.5

Calculation

Weight of sample (RAP) place in centrifuge extractor(A)= 200gm

Weight of the extracted sample(RAP) (B) = 195gm

Bitumen contest (percent of extracted sample) =((A-B)/B)X100 = ((200-195)/195)X100 = 2.56%

Table Result of Bitumen Content test on Recycled Asphalt Pavement (Size Lies B/W 20 to 4.75mm) and RAP (Size below 4.75mm)

Sample	RAP (size lies b/w 20 to 4.75mm)	RAP (size below 4.75mm)
Weight of sample (RAP) place in centrifuge extractor	200gm	200gm
Weight of the extracted sample (RAP)	195gm	190gm
Bitumen content (percent of extracted sample)	2.56%	5.263%

4.7Gradationof Aggregate

Proper gradation is one of the most important factors in producing workable and voidless concrete. If the proportion of coarse aggregate in sample is well graded then therewill be minimum voids in the sample and hence minimum paste is required to fill thevoids . Minimum paste mean less quantity of cement and hence less quantity of wateris required and this lead economy and higher strength. Thus Proper gradation ofaggregate plays an important role in concrete and should be determine carefully.The sieve analysis of coarse and fine aggregate can be determine by using a series of sieves 80 mm, 40 mm, 20 mm, 10 mm,, 4.75 mm for coarse aggregate, and 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 microns, 300 microns and 150micron for fine aggregate . The procedure given in IS code: 383-1970 is used to determine the sieve of fine aggregate (sand) . coarse aggregate (20 mm and 10 mm) andRAP aggregate respectively.

Sieve Analysis of Fine Aggregate (Sand)

Total weight of fine aggregate has taken = 1500 gm

% of passing =((total weight-cumulative wt of retained aggregate)/total weight) x 100.

Table Sieve analysis of fine Aggregate

Sieve size (mm)	Wt of retained Aggregate on Sieve (gm)	Cumulative wt of Retained aggregate on sieve (gm)	% of passing aggregate through The sieve
10	-	-	100
4.75	59	59	96.1
2.36	239	298	80.1
1.18	303	601	59.9
600	314	915	39.0
300	384	1299	13.4
150	146	1445	3.7

The gradation of fine aggregate is compared with grading of fine aggregate described in IS: 383-1970 (page- 11) in Table 4, to determine the grading zone of fine aggregate asshown in Table

Sieve Analysis of Coarse Aggregate (20 mm and 10 mm) And RAP

The weight of coarse aggregate of size 20mm, 10 mm and weight of Rap aggregate is taken for sieve analysis are 3980 gm, and 2520 gm respectively. Therefore, percentage of passing from series of sieve is given by:

% Passing = ((Total weight –cumulative wt of retained aggregate)/ total weight x100

Table 4.9 Shows the gradation of the tree types of coarse aggregates and also shows the maximum and minimum passing limits according to is 383 -1970 it is also noticed that the grading of any individual coarse aggregate does not fit the requirements of IS : 383-1970. So proportioning of aggregates is required to meet the graduation requirement.

Table Sieve Analysis coarse Aggregate (20 mm and 10 mm) and RAP

Sieve (mm)	% of passing aggregate through the sieve (20 mm)	% of passing aggregate through the sieve (10 mm	% of passing aggregate through the sieve (RAP)	Permissible gradation as per IS : 383 – 1970
20	98.3	100.0	99.0	95-100
16	40.7	100.0	90.0	-
12.5	5.3	96.0	73.5	-
10	2.8	79.0	53.4	25-55
4.75	0.7	17.7	9.1	0-10
2.36	0.1	1.3	1.4	-

Proportioning of Aggregates

The proportioning of aggregates is required due to the following reasons

- Requirement of graduation is to be met to achieve the desired maximum density
- Aggregate of required gradation are not available.

There are various methods to determine the proportioning of aggregate. Methods are as follows.

- Triangular chart method: It is used where three materials are to be mixed.
- Rothfutch' s method: It is used where a number of materials are to be mixed .
- Trial and Error method/ Analytical method: it can be used for mixing number of material.

Here, the analytical method is adopted for the mix design M35 grade cement concrete. In the mix design M35, the fresh coarse aggregate of size 20mm and 10mm are mixed in proportion A:B::50:50 respectively to meet the grade requirement as shown in Table 4.8. Where, A and B denote the fresh coarse aggregate of size 20 mm and 10mm respectively.

Table Grading of All in Aggregate

	Percent By weight Passing the Sieve				
IS sieve (mm)	Aggregate designation		IRC 44-2008 specified grading for graded aggregate in table 1		Observed grading of the Design mix (Proportioning A:B::50:50)
	(20 mm) (A)	(10 mm) (B)	Range	Mean	
20	98	100	95-100	97.5	99
10	2.8	79	25-55	40	40.9
4.75	1	18	0-10	5	9.5

Compressive Strength Test

Compressive strength of concrete is important for resistance to compressive stresses. Cubical specimens of size 150mm were cast for conducting compressive strength test for each mix (A to E). The compressive strength test is carried out by using compressive strength testing machine as shown Figure above. The cubical specimen of size 150 mm is placed in compressive testing machine and the load is applied without shock and increased continuously at a rate of approximately 16 N/mm2 per minute until the resistance of the specimen to the increasing load breaks down.

The maximum compressive load that a specimen bears before crushing is known as the compressive strength for that specimen. The test carried at the end of 7 days and 28 days of curing. Average of three cubes, in all the mixes, is taken as the compressive strength after 7 and 28 days of curing respectively.

Table Result of compressive strength test on concrete cube after 7 days of curing

Serial no	Mix design	Weight of concrete cube (Kg)	Compressive strength after 7 days (N/mm^2)		Percentage variation with respect to mix design Mix M35	Remarks
			Individual specimen	Average of three cubes		
1	Mix A (0% RAP)	8.294	28.35	26.95	-	Decrease
2		8.147	26.89			
3		8.188	25.61			
4	Mix B (25 % RAP)	8.088	24.22	23.22	13.84%	
5		8.070	23.20			
6		7.935	22.24			
7	Mix C (50 % RAP)	7.991	19.50	18.36	32.08%	
8		7.843	18.20			
9		8.137	17.40			
10	Mix D (75 % RAP)	7.997	16.67	15.59	33.76%	
11		7.771	15.34			
12		8.068	14.78			
13	Mix E (100 % RAP)	8.083	15.50	14.70	34.51%	
14		7.946	14.90			
15		8.095	13.70			

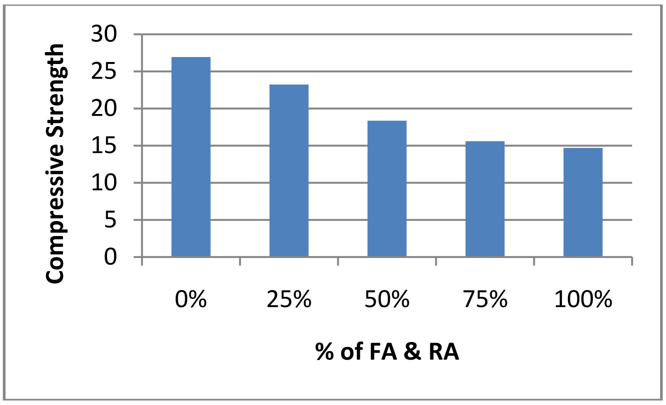

Fig. Compressive Strength after 7 Days

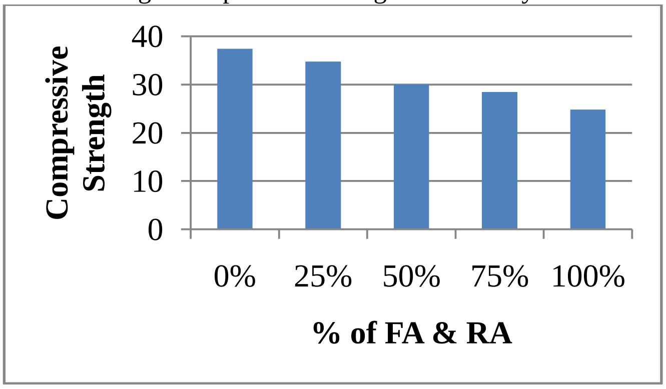

Fig. Compressive Strength after 28 Days

VI. CONCLUSIONS

This present research work has been selected to examine the physical and mechanical properties of RAP used as coarse aggregate in cement concrete. In this project, various tests on aggregate (both virgin and RAP) are carried out in laboratory to determine the physical and mechanical properties of aggregates. Compressive strength and other various properties like crushing strength, toughness, specific gravity et. tests are carried out on the fresh asw ell as recycled aggregate. Based on the test results, the following conclusions are drawn:

Based on the Properties of aggregates

- Presently RAP aggregate is treated as waste material and is economical than fresh aggregate. Therefore concrete made up of RAP aggregate will natural be economical.
- It is observed that specific gravity of fresh aggregate is in the range of 2.36 to 2.55 and that of RAP is 2.5.
- It is observed that the water absorption of fresh aggregate is 1.63 and that of RAP is 1.3. This indicates that the workability of concrete mix will reduce at same water cement ratio, as the percentage of RAP aggregate in cement concrete increases.
- It is observed that the gradation of recycled asphalt pavement aggregate satisfied the desired grade requirement specified by IS code: 383-1970. This means that fresh coarse aggregate of size 20mm and 10mm can be partially/fully replaced by recycled asphalt pavement aggregate.
- It is observed that the crushing value of RAP and fresh aggregate are 17.28% and 17.09% respectively. Indicating in no significant difference between the two.
- It is also observed that the value of all the properties of RAP aggregate except bitumen content, does not exceed to the permissible limits for mix designs specified by IS code: 383-1970. Thus the recycled asphalt pavement aggregate used in present study is suitable for concrete mix designs.

Based on the Compressive strength of concrete

- It is observed that the compressive strength of the recycled asphalt pavement concrete mixes i.e. mix B, mix C, mix D, and mix E as compare to fresh concrete mix M35 (mix A), after 7day, is laser by 13.84%, 32.08%, 33.76% and 34.51% respectively. This indicates that there is a gradually reduction in the compressive strength of concrete mix (M35) (after 7 days) as percentage of RAP content increase. It is also found that the minimum compressive strength of the concrete mix (M35) made of a RAP aggregate after 7 days is approximately 60% to that of the fresh aggregate concrete mix (M35).
- It is observed that the compressive strength of recycled asphalt pavement concrete mixes I.e. mix B, mix C, mix D, and mix E as compare to fresh concrete mix M35 (mix A), after 28 days is lesser by 8.02%, 20.09%,24.91% and 33.80% respectively. This indicates that there is a gradually reduction in the compressive strength of concrete mix (M35) (after 28 days) as percentage of RAP content increases. It is also found that the minimum compressive strength of the concrete mix (M35) made up of RAP aggregate after 28 days is approximately 67% to that of the fresh concrete mix (M35).
- It is observed that mixing of RAP reduces the rate of gain of compressive strength as compared to fresh aggregate.
- The Scope for the Further Study.
- The study can be extended on cement concrete mixes with RAP in following directions
- Effect of water cement ratio,
- Effect of admixtures and
- Post 28 days strength characteristics can also be studied

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