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Experimental Study on Recycling of Bituminous Aggregate in Cement Concrete

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Abstract: ***Recycling of bituminous aggregates in cement concrete has been selected for the present study to determine suitability of recycled material in road construction. This will help in achieving economy in road construction as well as saving on environment degradation in term of reduced mining and less pollution. Construction and maintenance of roads and highways involve millions of tonnes of aggregate.***
Considering the scarcity of fresh aggregate, replacement of part of the fresh aggregate with recycled aggregate is considered in the present study. Construction of the road is quite cost intensive. Material alone cost more than 60% of the total construction cost, out of which aggregate cost component, is approximately 30%. We can use recycled aggregate in place of fresh aggregate in construction of road and provide economy to the project. For making best use of recycled aggregates, it is essential to study the suitability of the same in various pavement components. In the present study recycled aggregate are used in Granular Sub Base (GSB) and Wet Mix Macadam (WMM).

I. INTRODUCTON

Concrete is a composite construction material composed primarily of aggregates, cement and water. In general, aggregate make up 60% to 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 per portioning of aggregate should be given careful attention. The aggregate is generally coarse gravel or crushed rocks such as limestone, granite along with a fine aggregate such as sand or stone dust.

Bilk of pavement structure is formed by aggregate. The major function of 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 aggregates 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 rail roads.

Recycled asphalt pavement (RAP) is the removed and reprocessed pavement material containing asphalt and aggregate. The use of recycled asphalt aggregate has become a common practice in the construction of new and reconstruction of old, hot mix asphalt pavements.

But little research has been done to examine the 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 pavements used in the present study is obtained from the debris of dismantled asphalt road

Importance of Research Topic

The topic " EXPERIMENTEL STUDY ON RECYCLING OF BITUMINOU AGGREGATE IN CEMENT CONCRETE " has been selected for the present study to examine the physical and the mechanical properties of RAP incorporated in cement concrete.

The aim of this project is to determine the strength characteristic of RAP for application in high strength concrete, which will give a better understanding on the properties of concrete with RAP as an alternative material to fresh coarse aggregate in concrete. This will help in achieving economy in road construction as well as saving environmental degradation in term of reduced mining and less pollution. Use of RAP will also conserves resources, landfill space and will generate profit for the recyclers.

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A. Scope of the Study

In this project, the mix design of M30 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 M30 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% C
6) Water cement ratio in total of five batches of concrete mix has kept constant as 0.45.

B. Objective of the Study

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:

1) Collection of study material.
2) 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.
3) Mix Design of M30 grade cement concrete based on IS code and IRC: 44-2008.
4) Check for compressive strength as well as flexural strength.

II. LITERATURE REVIEW

A. Introduction

Recycled asphalt pavement has been widely used in the United States since the 1970s and is a major benefit to the paving industry. According to Kelly (1998) about 100 million ton worn out asphalt pavement is recovered annually and about 80 % of recovered material is currently recycled and the remaining 20% is used in landfills. Two thirds of recycled material is used as aggregate for road base and remaining one third of recycled material is reused as aggregate for new asphalt hot mixes.

B. Historical Background

Recycled asphalt pavement is being used more widely throughout the world in various applications. Most of the RAP is put back into the roadways as a base or surface material. The use of recycled material in Portland cement concrete has become more and more popular in recent year.

Murshed Delwar et al. (1997) investigated the use of combinations of coarse and fine RAP aggregate in normal concrete mixes and compared the results of compressive strength to conventional mixes with 0.4 and 0.5 water cement ratios. Compressive strength values were found to decrease with the increase in RAP content.

Baoshan Huang, et al (2005) found that RAP could be incorporated into Portland cement concrete without any modification to the conventional equipment or procedures. Without any treatment, there was a systematic reduction in compressive and split tensile strength with the incorporation RAP in concrete.

Salim Al-oraimi, et al. (2007), used RAP as a coarse aggregate, substitute in two different normal concrete mixes having 28 days cube compressive strengths of 33 and 50 MPa. RAP was used with 25, 50, 75, 100% replacement of coarse aggregate. According to test result, the slump decreased with the increase in RAP content. The compressive and flexural strength decreased with the increase in RAP content. The surface absorption was not significantly affected by the addition of RAP. The results indicated the viability of RAP as an aggregate in non-structural concrete applications.

The percentage of RAP should be limited according to the application. Low slump should also be considered when utilizing RAP in the mixes.

Fidelis o.okafor (2010) found 'that the strength of concrete made from RAP is dependent on the bond strength of the "asphalt-mortar" (asphalt binder-sand-filler matrix) coatings on the aggregates and may not produce concrete with compressive strength above 25 MPa. He prepared six concrete mixes of widely differing water/cement ratios and mix proportions were made using RAP as coarse aggregate. The properties tested include the physical properties of the RAP aggregate, the compressive and flexural strengths of the concrete. These properties were compared with those of similar concretes made with fresh aggregate. However, for middle and low strength concrete, the RAP material was found to be comparable with natural gravel aggregate.

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In the present study virgin coarse aggregate is replaced by RAP in different proportions i.e. 0, 25, 50, 75 and 100. Proportion of aggregate is modified accordingly to meet the required gradation and their corresponding compressive and flexural strength were studied. Water cement ratio in all batches is kept constant as 0.45.

C. *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 horn on a bulldozer and/or 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 facility, 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:

1) Cold milling of existing road and
2) Hot mix asphalt plant.
3) Above two are discussed briefly given following section.

D. *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 free of 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 (Figure 2.1) .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.



Figure 1. Cold Milling Process

E. *Hot Mix Asphalt Plant*

Hot recycling or hot mix recycling (Figure 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 (HMA) 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.

1) Concrete Kerb and Gutter Mix

Recycled aggregate have been used as concrete kerb and gutter mix in Australia. Stone ;,-
(1999) used 1 Omm recycled aggretate and blended recycled sand for concrete kerband gutter mix in the Lenthall Street project in Sdyney (Figure 3).



Figure 2. Recycled Aggregate as Road Kerb

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2) *Granular Base Course Materials:* According to Market Development Study for Recycled Aggregate Products (2001), recycled aggregate are used as granular base course in the road construction. It also stated that in many applications, recycled aggregate will proved to be superior to fresh aggregate when used as granular base course in roads construction. For example if a new road is to be built over an area of soft, wet subgrade areas, recycled concrete will serve to stabilize the base and provide an improved working surface for constructing pavement structure (Figure 2.4).



Figure 3. Recycled Aggregate as Granular Sub Base

3) *Embankment Fills Materials:* Market Development Study for Recycled Aggregate Products (2001) states that recycled aggregate can be used in embankment fill. The reason for being able to use in embankment fill is same as is for it's used in granular base course construction.

4) *Building Blocks:* Recycled aggregate can be used as an ingredient in building block. Optiroc AS has produced Leca masonry sound insulation block using 30% recycled concrete aggregate (size 4-10mm). According to Jacob mehus et al (2002), Leca masonry sound insulation blocks that produced had met all the requirements during the laboratory testing (Figure 2.5).



Figure 4. Recycled Aggregate Used As Building Block

5) *Backfill Materials:* Norwegian Building Research Institute (2002) conducted various full scale laboratory tests and found that recycled concrete aggregate (RCA) would function well as backfill materials in pipe zone found in utility trenches (Figure 2.6).



Figure 5. Recycled Aggregate as Backfill Materia

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III. ADVANTAGES

There are many advantages associated in using the recycled aggregate as listed below.

1) *Conservation Of Virgin Aggregate:* The supply of virgin aggregate in many areas of the United States is or becoming limited. In such areas, the use of recycled aggregate is beginning to serve as an environment friendly and economically viable solution. Recycled aggregate is also an alternative material for natural aggregate that can lead to a decrease in energy consumption for hauling and producing aggregate. In this way, by using the recycled aggregate as alternative material for natural aggregate, can conserve the/virgin aggregate for long life.
2) *Saving In Transportation Cost:* According to Kajima Corporation, annual report (2002), Kajima is developing a method of recycling crushed concrete used in construction, known as the Within-Site Recycling System, as shown in Figure 2.7. Every activity can be done on the construction site through this system, including processing of recycled aggregate, manufacturing and reuse. This can save energy to transport the recycled materials to the recycling plants.



Figure 6. Recycled Aggregate Concrete For Within Site Recycling

3) *Saving in Cost:* According to Environmental Council of Concrete Organization, the cost of recycling can be reduced up to $4.00 per ton to crush, as well as otherexpenses. But by eliminating the cost of removing the old concrete and factoring. In savings on disposal costs, potential use of recycled fines, and potential road damage from transport of virgin or waste materials, some states have estimated savings of up to 50% to 60% from using recycled aggregates versus buying new aggregate.
4) *Market For Recycled Concrete Is Wide:* According to Environmental Council of Concrete Organization, recycled concrete aggregate can be used for sidewalk, kerbs, bridge substructures and superstructures, concrete shoulders, residential driveways, general and structural fills. It is also mentioned that recycled concrete aggregate can be used in sub bases and support layers such as un-stabilized base and permeable bases.

IV. DISADVANTAGES

Although there are many advantages of using recycled aggregate. But there are still some disadvantages in recycled aggregate.

1) *Hard To Have Permit:* It is hard to get the permit for the machine required for recycling purpose which in turn depends on the local or state regulations whether this technology is implemented or not.
2) *Lack Of Specification And Guidelines:* According to Kawano (1995), there is no specification or any guideline when using recycled concrete aggregate in the constructions. In many cases, the strength characteristic will not meet the requirement when using recycled concrete aggregate. Therefore, more testing should be considered when using recycled concrete aggregate.
3) *Water Pollution:* Alex Wilson et.al (2012) stated that an average seven gallons of water are required to discharge for each cubic yard of concrete production. He also stated that the alkalinity levels of wash water can increase up to pH 12 which is toxic for fish and other aquatic life. Thus wash water from concrete production caused water pollution when it is drained to the river or other drainage.

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V. CONCLUSIONS

The research work on the topic "Recycling of Bituminous Aggregate in Cement Concrete - An Experimental Study" has been selected for the present study to examine the physical and the mechanical properties of RAP used as coarse aggregate in cement concrete. In this project, various tests on aggregates (both virgin and RAP) are carried out in laboratory to determine the physical and mechanical properties of aggregates. Compressive strength and flexural tensile strength tests are carried out on the concrete mixes, made up of virgin and RAP aggregates in different proportion (mix A to E). Based on the test results, the following conclusions are drawn:

A. Based on the Properties of Aggregates

Presently RAP aggregate is treated as waste material is economical then fresh aggregate therefore concrete made up of RAP aggregate will naturally be economical.

1) From table 4.6, it is observed that specific gravity of fresh aggregate is in the range of 2.69 to 2.68 and that of RAP is 2.49,which is less than 8.5 % than fresh aggregate.

2) From table 4.6, it is observed that the water absorption of fresh aggregate is 0.5 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.

3) From table 4.9, it is observed that the gradation of recycled asphalt pavement aggregate satisfied the desired gradation 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.

4) From table 4.6, it is observed that the crushing value of RAP and fresh aggregates are 17.36% and 17.09% respectively. Indicating in no significant difference between the two.

5) From table 4.6, It is 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 design.

B. Based On Compressive Strength Of Concrete

1) From table 6.1 it is observed that the compressive strength of the recycled asphalt pavement concrete mixes i.e Mix B Mix C , Mix D mix E as compared to fresh concrete Mix M30(mix A),after 7days, is lesser by 10.46%, 36.8%,38.4%,and 39.5% respectively. This indicates that there is a gradually reduction in the compressive strength of concrete mix (M30)(after 7 days) as percentage of RAP content increases. It is also found that the minimum compressive strength of concrete mix (M30) made up of Rap aggregate after 7 days is approximately 60% to that of the fresh aggregate concrete Mix (M30).

2) From table 6.2,It is observed that the compressive strength of recycled asphalt pavement concrete mixes i.e mix B, Mix C, mix and mix E as compared to fresh concrete mix M30(Mix A), after 28days is lesser by 6.9%,18.1%,23.9%and32.8%respectively.This indicates that there is a gradually reduction in the compressive strength of concrete mix (M30) (after 28 days) as percentage of RAP content increases. It is also found that the minimum compressive strength of the concrete mix (M30) made up of RAP aggregate after 28 days is approximately 67% to that of the fresh concrete mix (M30).

3) From table 9.3, it is observed that mixing of RAP reduces the rate of gain of compressive strength as compared to fresh aggregate.

C. Based On Flexural Strength Of Concrete

1) From table 6.4, it is observed that the flexural tensile strength of recycled asphalt pavement concrete mixes i.e mix B , mix C ,mix D and mix E as compared to fresh concrete mix M30 (Mix A),after 28 days is lesser by 4.1%,8.2%,19.0%and 29.1% respectively. This indicates that there is a gradually reduction in the flexural tensile strength concrete mix (M30)(after 28 days) as percentage of RAP content increases. It is also found that the minimum flexural tensile strength of concrete mix (M30) made up of RAP aggregate after 28 days is approximately 70% to that of fresh concrete mix (M30).

2) From the result It is observed that inclusion of RAP affects the compressive strength More than the flexural strength.

Hence, at location where low strength of concrete is required, the recycled asphalt pavement aggregate may be a used as alternative material for fresh coarse aggregate.

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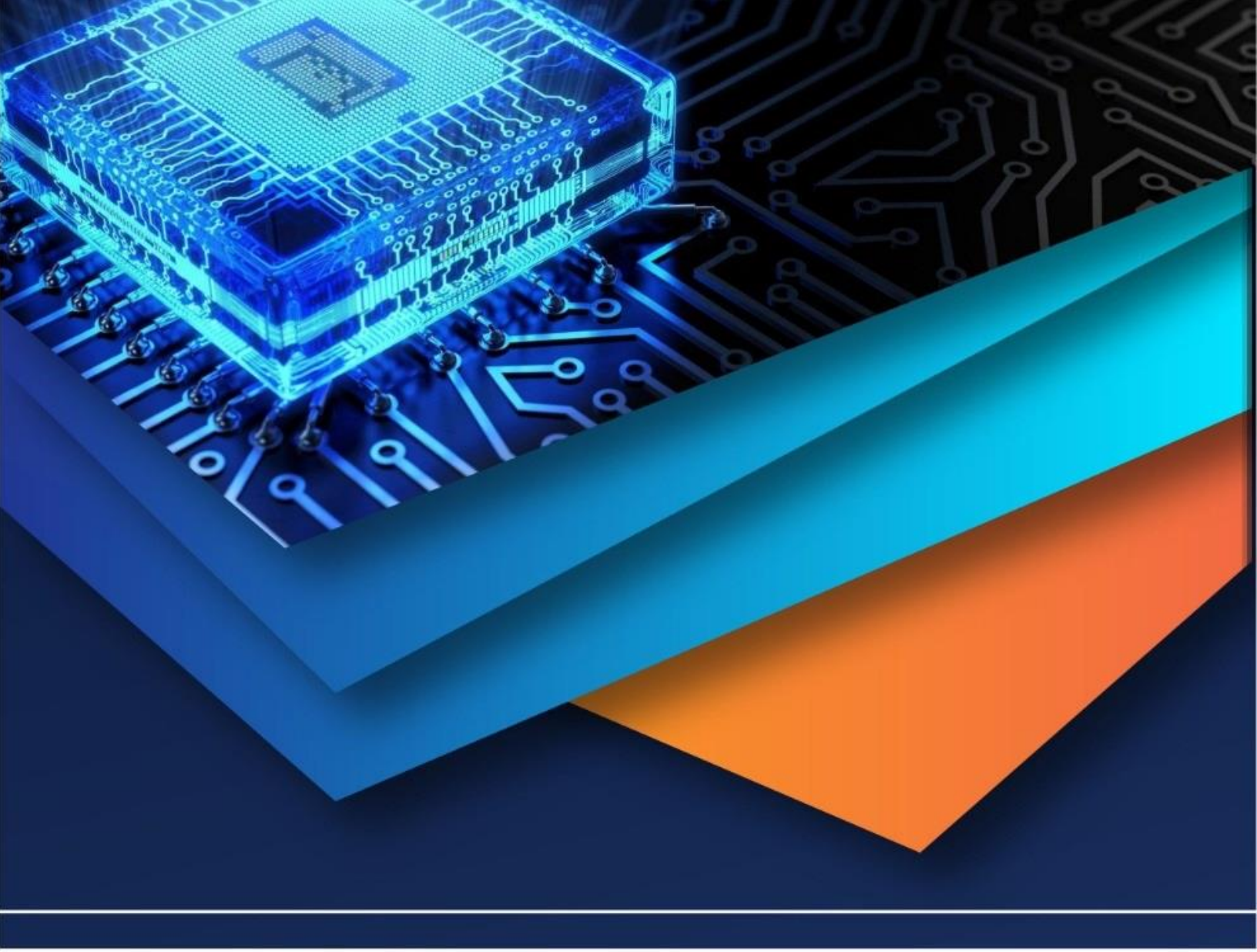
VI. THE SCOPE FOR THE FURTHER STUDY

The study can be extended on cement concrete mixes with RAP in following directions.
Effect of water cement ratio
Effect of admixtures
Post 28 days strength characteristics can also be studied.

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