# PAVEMENTS USING RECLAIMED AGGREGATES

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## *ABSTRACT*

*Eco friendly construction techniques are gaining immense importance nowadays. Many innovations have come in pavement construction and design. The use of reclaimed aggregates in constructing pavements is one among them. Reclaimed aggregates come mainly from two sources - construction & demolition waste and asphalt pavements. The optimized use of reclaimed aggregates along with fresh aggregates helps decrease construction cost without compromising strength and durability. It also minimizes the use of virgin aggregate and helps decrease crude oil import for producing paving bitumen. Reclaimed material is first crushed and screened before using. Tests are then conducted to analyse its properties. Only those batches which satisfy standard conditions are used. Reclaimed aggregate pavements hence help pavement rehabilitation with minimum energy expenditure. This paper deals with the tests on reclaimed aggregate and their property study. The various sources and means of retrieving aggregate from reclaimed material are also dealt with.*

## *KEYWORDS*

*Reclaimed Aggregate, Pavement Construction, Construction Method*

## 1. INTRODUCTION

Industrialization and urbanization exposes challenges of various concerns pertaining to depletion of resources like aggregates. The amount of waste produced from building demolition is continuing to grow due to increasing need for repair and renewal of buildings. Within the construction industry, road design and construction is one of the largest economic and material consuming industries in the world. Emphasis on material conservation, reuse and recycling had encouraged a number of government and highway agencies to commission research and investigations to use recycled material in pavement construction.

The use of reclaimed material considerably saves material, money and energy, without compromising the strength. Its importance rises in the light of increasing cost of bitumen, scarcity of good quality aggregate and priority towards the preservation of environment. Recycled aggregates are the materials of future. The application of recycled aggregates has been started in many construction projects in European, American, and Asian countries. Some countries have even relaxed infrastructural laws for the increased use of recycled aggregates. This sustainable practice is an effective means of pavement rehabilitation as the materials which have reached the end of their service life are still made valuable. In Europe and US, studies have concluded that 80% of the recycled material is used in construction of roads. However, the quality of the

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pavement constructed depends on the origin, variability, stocking and production conditions of the reclaimed material. The strength of the reclaimed material can be improved through the use of rejuvenators. Considering the material and construction cost alone it is estimated that using recycled materials, saving ranging from 14%- 34% can be achieved. Hence bituminous pavements using reclaimed aggregates can evolve into a regular practice for sustainable construction.

## 2. SOURCES OF RECLAIMED AGGREGATES

The use of reclaimed materials enables to improve the quality of infrastructure in sustainable ways. This includes reclaiming aggregates and rejuvenating their component parts for use in new pavements. The two major sources to obtain them are- Construction & Demolition waste (CDW) and Reclaimed Asphalt from old pavements (RAP).

### 2.1 Construction and Demolition Waste

Over the year's construction and demolition waste has been increasing, while the amount of landfill available to contain this waste is decreasing. Retrieving aggregates from CDW is thus a viable solution. The use of these materials as recycled base course in new roadway construction has become most common in the last 20 years.

#### 2.2 Asphalt Pavements

Existing asphalt pavements can be removed and reprocessed to obtain aggregates. Since aggregates obtained from asphalt pavements are coated with bitumen, they have reduced water absorption qualities.

## 3. RETRIEVING AGGREGATE FROM RECLAIMED MATERIAL

RAP can be removed from existing roadways using one of the two basic methods. The pavement can be broken and "ripped" up, or it can be milled. While ripping up pavement, the obtained RAP must then be processed through crushers like impactor crushers. After it leaves the impactor, it must be screened and separated into different material sizes and stockpiled.[1][5]

Unless the entire thickness of roadway is being removed, milling the road is far superior to ripping it up because of the condition in which this process leaves both the roadway and the RAP. By milling each individual layer of pavement from the road, material of differing qualities can be kept separate. In addition, milling offers the opportunity to significantly improve the surface smoothness of the milled pavement, often eliminating the need for additional preparation before paving. Milling a road versus overlaying with new pavement offers many important benefits. Overlaying often requires additional work in raising the elevation of shoulders and utilities. Overlays also add dead weight to bridges and overpasses. Milling involves grinding and collection of the existing hot mix asphalt (HMA).The typical aggregate gradation is obtained through pulverization of the material which is typically performed with rubber tired grinder.[6]

The production of reclaimed cement aggregate (RCA) involves crushing the CDW to a gradation comparable to that of typical roadway base aggregate. Fresh RCA contains high amount of debris and reinforcing steel which has to be removed through processing. The material is first crushed in a jaw crusher that breaks the steel from the material and provides an initial crushing of concrete. The material is sent down a picking belt from where steel is removed. The remaining concrete material is further crushed and screened to pre-determined gradation.

## 4. Advantages And Disadvantages

### 4.1 Benefits:

- Reduce the production of greenhouse gas emission and other pollutants by reducing the need to extract raw materials and ship new materials over long distances.
- Conserves land fill spaces, reduces the need for new landfills and their associated costs.
- Saves energy and reduces the environmental impact of producing new materials.
- Proves economic

### 4.2 Barriers:

- Quality assurance and quality maintenance can be challenging.
- Impurities in reclaimed materials can result in decreased stability and strength.
- Dust generation during aggregate retrieval may possess hazards to workers and environment

## 5. Cost Saving

The economical aspect of using reclaimed aggregate is illustrated through an example: [7]

Consider an existing four-lane national highway with a total length of 120 km which is to be made a six-laned highway. Due to construction of under passes and flyovers a total of about 30 km of the existing four lanes of bituminous pavement will get buried if not reclaimed and recycled. The total tonnage of bitumen, which will be buried, is estimated to be about 7,000 tons which has a value of more than 22 crore rupees. The total tonnage of aggregate in the bituminous pavement, which will also get buried, is estimated to be about 165,000 tons which has a value of over 6 crore rupees. So we will have a gross savings of over 28 crore rupees. The estimated cost of cold milling and transport of RAP to hot mix plant for recycling is about 8 crores. Therefore, a net saving of rupees 20 crores can be realized on this six-laning project if hot mix recycling is implemented by the National Highway Authority of India (NHAI). There are many projects of this nature which can save us hundreds of crores. The one-time cost of modifying an existing asphalt batch plant to do hot mix recycling in India is only 20 lakhs rupees.

Besides huge savings in cost, we will also have to obtain less virgin aggregate from our stone quarries and also will have to import less crude oil to produce the paving bitumen. In some states such as Punjab and Haryana where stone quarries are prohibited, aggregate is transported from the neighboring states covering over 150 km that makes the aggregate very expensive.

Reclaimed aggregates obtained from demolition material can reduce the cost of transporting the material to the landfill. The expense needed for the disposal can be minimized. Also the cost of processing natural aggregate can be avoided. The use of aggregates from reclaimed asphalt pavement also minimizes transportation cost.

## 6. MATERIAL CHARACTERISATION

Reclaimed aggregate for conducting laboratory investigation was collected from various demolition sites. The sieve analysis of the demolition waste gave the following results

Table 1- Gradation of aggregates from sieve analysis

| Sieve size(mm) | Obtained Gradation | | | Requirement as per MORTH specification (Table 500.17) | Average of Obtained Gradation |
|---|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | | |
| 19.0 | 90 | 94 | 96.2 | 90-100 | 93.4 |
| 13.2 | 67 | 66 | 68 | 59-79 | 67 |
| 9.5 | 53 | 55.5 | 58 | 52-72 | 55.5 |
| 4.75 | 38 | 36.75 | 39 | 35-55 | 37.91 |
| 2.36 | 28 | 30.5 | 29 | 28-44 | 29.16 |
| 1.18 | 20.4 | 20.4 | 21.60 | 20-34 | 20.8 |
| 0.6 | 15 | 18 | 17.4 | 15-27 | 16.8 |
| 0.3 | 10.4 | 10.4 | 10.3 | 10-20 | 10.36 |
| 0.15 | 4 | 4 | 7 | 5-13 | 5.0 |

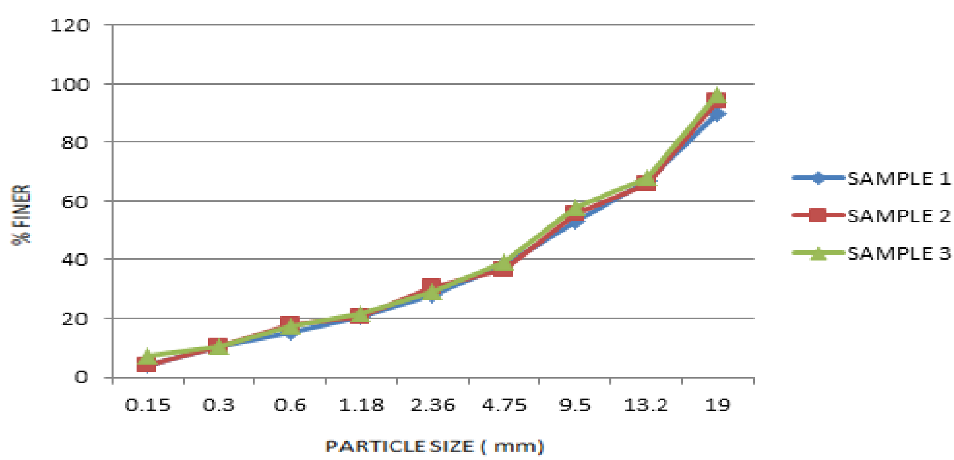


Figure 1:Particle size distribution curve

Sample 1-Flat demolition waste
Sample 2-House demolition waste
Sample 3-Shop demolition waste

The particle size distribution curve suggested that the demolition waste showed similar grain size distribution irrespective of the source. The obtained material was greyish black in appearance. The test sample was shaped angular with a rough texture due to the hand crushing.

# 7. LABORATORY INVESTIGATION

Table 2 Test Results [4][3] [2]

| Sl No. | Property | Test | Result | Standard | IS Code |
|---|---|---|---|---|---|
| 1 | Specific Gravity | Specific Gravity | 2.5-2.72 | 2.6-2.8 | IS 2386 Part III |
| 2 | Toughness | Impact Test | 25-27% | Maximum 24% | IS 2386 Part IV |
| 3 | Porosity | Water Absorption | 0.3-2% | Maximum 2% | IS 2386 Part III |
| 4 | Shape | Combined Flakiness and Elongation Index | 26% | Maximum 35% | IS 2386 Part I |
| 5 | Hardness | Los Angeles Abrasion Test | 27% | Maximum 30% | IS 2386 Part V |

# 8. MIX DESIGN

## 8.1 Bituminous Macadam

### 8.1.1 Materials

a.Broken stone aggregate 20 mm and down (Aggregate A)
b.Broken stone aggregate 12 mm and down (Aggregate B)
c.Broken stone aggregate 6 mm and down (Aggregate C)
d. Quarry sand (Aggregate D)
e. Bitumen -60/70 grade

### 8.1.2 Grading of Aggregates supplied

Table 3Gradation of aggregates and their blends for bituminous mixture

| Sieve Size (mm) | Percentage Passing | | | | AdoptedGrading A: B: C: D | Specified Grading (Table 500.7) Grading2 |
|---|---|---|---|---|---|---|
| | AggA | Agg B | Agg C | Agg D | | |
| 26.5 | 100 | 100 | 100 | 100 | 100 | 100 |
| 19 | 93.9 | 100 | 100 | 100 | 97.87 | 90-100 |
| 13.2 | 16.4 | 92.3 | 100 | 100 | 68.82 | 56-88 |
| 4.75 | 0.7 | 6.9 | 69.1 | 100 | 16.8 | 16-36 |
| 2.36 | 0.3 | 2.55 | 47.55 | 16.6 | 16.66 | 4-19 |
| 0.3 | 0 | 0.85 | 8.5 | 15.3 | 4.3 | 2-10 |
| 0.075 | 0 | 0 | 0 | 0 | 0 | 0-8 |

### 8.1.3 Mix Proportioning

Based on calculations, the proportions which satisfied the requirements given in table 500.7 of MORTH specification for grading 2 aggregates are as follows:

Aggregate A : 35%
Aggregate B : 25%
Aggregate C : 30%
Aggregate D : 10%

As per Table 500.7 of MORTH specifications fifth edition (2013) bitumen content % by weight of total mixture is 3.4

Optimum Binder Content : 3.4% by weight of total mix
: 3.5 % by weight of aggregate

Table 4 Materials required

| Materials | % by weight of mix |
|---|---|
| Aggregate A-20 mm | 33.8 |
| Aggregate A-12 mm | 24.2 |
| Aggregate A- 6 mm | 28.9 |
| Aggregate A- Dust | 9.7 |
| Bitumen | 3.4 |

## 8.2 Bituminous Concrete

### 8.2.1 Materials

a.Broken stone aggregate 12 mm and down (Aggregate A)

b.Broken stone aggregate 6 mm and down (Aggregate B)
c. Quarry sand (Aggregate C)
d. Bitumen -60/70 grade

**8.2.2 Grading of Aggregates supplied**

Table 5Gradation of aggregates and their blends for bituminous mixture

| Sieve Size (mm) | Percentage Passing | | | AdoptedGrading A: B: C: D | Specified Grading (Table 500.7) Grading2 |
|---|---|---|---|---|---|
| | Agg A | Agg B | Agg C | | |
| 26.5 | 100 | 100 | 100 | 100 | 100 |
| 19 | 100 | 100 | 100 | 100 | 100 |
| 9.5 | 92.3 | 100 | 100 | 97.69 | 70-88 |
| 4.75 | 6.9 | 69.1 | 100 | 62.8 | 53-71 |
| 2.36 | 2.55 | 47.55 | 16.6 | 21.67 | 21-58 |
| 0.3 | 0.85 | 8.5 | 15.3 | 8.925 | 8-28 |
| 0.075 | 0 | 0 | 0 | 0 | 0-10 |

**8.2.2 Mix Proportioning**

Based on calculations, the proportions which satisfied the requirements given in table 500.17 of MORTH specification for grading two aggregates are as follows:

Aggregate A : 30%
Aggregate B : 30%
Aggregate C : 40%

**8.2.2.1 Determination of optimum binder content**

To determine the optimum binder content for a particular gradation of aggregates by Marshall Method, test specimen were prepared with binder contents 4.5, 5, 5.5 & 6 percentages by weight of mix. For each binder content, three specimens were prepared and tested under the specified conditions.

Based on the observations, graphs were plotted with bitumen content on the X-axis and following values on Y-axis.

1. Marshall stability value
2. Flow value
3. Unit weight
4. Percentage weight in total mix.
5. Voids filled with bitumen.

From the graphs, optimum binder content was found out.

Optimum binder content : 6% by weight of total mix
: 6.4% by weight of aggregate

### 8.2.5 Job Mix Formula

The properties of mix corresponding to optimum binder content are as follows:

Table 6. Job Mix Formula

| Description | Test Results | Requirements as per Table 500.11 of MORTH specifications | Remarks |
|---|---|---|---|
| Optimum binder content (% of total mix) | 6 | Minimum 5.4 | Satisfies |
| Marshall stability value (kN) | 14 | Minimum 12 | Satisfies |
| Marshall flow value (mm) | 3 | 2.5 to 4 | Satisfies |

Table 7 Materials required

| Materials | % by weight of mix |
|---|---|
| Aggregate A-12 mm | 28.2 |
| Aggregate A- 6 mm | 28.2 |
| Aggregate A- Dust | 37.6 |
| Bitumen | 6 |

## 9. CONCLUSION

Test results confirm that reclaimed aggregate is a good substitute for fresh aggregate. In conclusion Reclaimed Asphalt Pavement and Reclaimed Cement Aggregate are not waste products and contributes in conserving natural resources and providing more miles of pavement from available revenues. As virgin resources become more limited and prices rise, the use of reclaimed aggregate in pavement construction is definitely an eco-friendly innovation

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