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# Subgrade Formation using Recycled Aggregate

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**Abstract: The topic 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).**

**Keywords: Recycled aggregate, Granular sub base, Road construction.**

## 1. INTRODUCTION

The Recycling of aggregate is a process in which used aggregate is reused for new construction. Use of recycled aggregate is not very common in India and other developing countries. There is huge requirement of the aggregate because of fast development in the infrastructure area. In order to reduce the usage of fresh aggregate, recycled aggregate can be used as a replacement materials. Recycled aggregate used in the present study is obtained from the debris of dismantled roads. The overall development of a country depends upon on a good and well-connected road network.

Various construction material used in the road construction include different grade of aggregate and binding material. 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 the 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. Different pavement mixes (such as bituminous macadam, dense bituminous macadam, semi dense bituminous macadam and bituminous concrete) require separate gradation as has been specifying by various agencies like A.S.T.M, B.S.I, I.S.I and IRC.

## II. BACKGROUND

### A. Britain

The Specification for Highway Works [1] allows the use of crushed concrete for several civil engineering purposes and it could be considered for many more depending on the quality of the particular recycled product. The use of industrial by-products and waste materials in building and civil engineering includes some comments on the use of waste materials in both road construction and building and it considers crushed concrete for sub-base and base course applications [2].

### B. Netherlands

The Netherlands has relatively poor reserves of natural aggregate and has become more dependent on recycled material for the construction of unbound aggregate road layers. Recycling in the Netherlands is mostly financed by the government and consequently recycled material has become an important source of aggregate for the Dutch construction industry. A research project was started in 1983 as a joint venture between the Delft University of Technology and the Road and Hydraulic Engineering Division in which the properties of recycled and conventional aggregates were examined. The

research programme consisted of laboratory and field testing. It was found that visual inspection of the material composition was important because of the influence of particle strength and stiffness on the behavior of unbound sub-base layers [3].

### C. Denmark

There is less incentive to recycle in Denmark than in Britain because natural aggregate is cheap and can be easily obtained [4]. The disposal of waste material is inexpensive and is not restricted. Recycled material produced by Danish demolition contractors is considered to be unsuitable for many purposes because demolition and recycling operations are not properly designed to produce high quality material. However, a "recommendation for the use of recycled aggregates for concrete of passive environmental class" was produced by the Danish Concrete Association [5].

### D. Japan

In Japan, land is used very efficiently and to avoid having to provide many dumping sites, the Japanese have examined the possibility of recycling demolition waste for use as base course material in road construction. In 1976, a stationary recycling plant was set up in the suburbs of Nagoya city. As a result of the success of this recycling plant, a report called The Technical Guide to Reuse of Waste for Pavements was written by the Japan Road Association in 1984 [8]. The amount of recycled material to be reused was expected to rise rapidly because the report written by the Japan Road Association (1984) was issued by the Ministry of Construction [9].

## III. MATERIAL USED FOR STUDY

The objective of present study is to evaluate the suitability of suing the recycled aggregate in road construction. So the material used for construction of GSB must be having fully or partially replaced recycled aggregate with fresh aggregates. A good GSB construction always has well graded particles of different sizes. In present study the composition of GSB considered as 40 mm, 20mm, 10 mm aggregates and stone dust. It is decided to use 20 mm aggregated as recycled aggregate as well as fresh aggregates.

## IV. TEST PROGRAM

It is very common to conduct the series of tests on the aggregates before using them in any road construction. Many properties of aggregates are needed in designing the pavement mixes. In present study the pavement mix considered for study is granular sub base. The GSB is prepared using the 20 mm fresh aggregates and recycled aggregates to evaluate the usability of recycled aggregates in pavement construction.

The testing program is divided in two phases. In first phase the tests are conducted on 20 mm fresh and recycled aggregates. It is helpful in deciding whether the recycled aggregates are acceptable for use in GSB construction. The details of tests on aggregates are as follows:

i) Aggregate Impact value test- on 20 mm recycled and fresh aggregates

ii) Water absorption test - on 20 mm recycled and fresh aggregates

iii) Bitumen content test – on 20 mm recycled aggregates

iv) Specific gravity test – for all the aggregates of GSB

v) Aggregate elongation test- on 20 mm recycled and fresh aggregates

The results on tests on aggregates are used to decide the suitability of 20 mm recycled aggregates in GSB construction. So GSB is prepared using 20 mm fresh as well as recycled aggregates. In second phase the tests are conducted on prepared GSB. The following tests are conducted on the GSB:

i) Standard proctor compaction test

ii) California bearing ratio test

iii) Permeability test

## V. RESULT AND DISCUSSION

### A. Tests on aggregates

The aggregate impact test has been standardized by the British Standard Institution and the Indian Standard Institution. The aggregate impact value indicates a relative measure of the resistance of aggregate to a sudden shock or an impact, which in some aggregates differs from its resistance to a slow compressive load. The method of test covers the procedure for determining the aggregate impact value of aggregates. The result of impact test on fresh aggregates is shown in Table-1. The result shows that impact value for the fresh aggregate is 14.81%.

**Table-1: Result of Aggregate Impact Value Test on Fresh Aggregate**

| Weight of collar =1259.5 gm |
|---|
| Weight of material=350 gm |
| Weight of material passing 52 gm through the IS 2.36 mm sieve |
| Impact value=14.85% |

The result of impact test on recycled aggregates is shown in Table-2. The result shows that impact value for the fresh aggregate is higher than the recycled aggregate value, but still the impact value of recycled aggregates are fairly good to use in GSB construction.

**Table-2: Result of Aggregate Impact Value Test on Recycled Aggregate**

| Weight of collar =1259.5 gm |
|---|
| Weight of material=354 gm |
| Weight of material passing 46.30 gm through the IS 2.36 mm sieve |
| Impact value=13.07% |

Water absorption gives an idea about the strength of aggregate. Aggregate having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness test. This test helps to determine the water absorption value of coarse aggregates as per IS: 2386 (Part III) – 1963 [13]. Formula used is Water absorption = [(A - B)/B] x 100%. The Table-3 shows the water absorption value for the recycled aggregate.

**Table-3: Result of Water Absorption Test of Recycled Aggregate**

| Weight of sample (before immersed in water) 1.8 kg |
|---|
| Weight of saturated dried sample 2 kg |
| Weight of oven dried sample 1.98 kg |
| Water absorption amount 1 % |

The Table-4 shows the water absorption value for the fresh aggregate. The result shows the higher water absorption value for the recycled aggregate as compared to the fresh aggregate i.e. 1% for recycled aggregate and 0.475 % for the fresh aggregate. As per the standard the water absorption in recycled aggregates is in the permissible limits, so can be used for the GSB construction.

**Table: 4: Result of Water Absorption Test of Fresh Aggregate**

| Weight of sample (before immersed in water) 1.8 kg |
|---|
| Weight of saturated dried sample 2 kg |
| Weight of oven dried sample 1.989 kg |
| Water absorption amount 0.55 % |

The asphalt content of asphalt-aggregate mixtures is determined by the bitumen extraction test. This test is used for product acceptance, quality assurance, process quality control and research activities. The asphalt content is expressed as a percent by dry weight of extracted aggregate corrected for asphalt mix moisture content and extractor error. This test is done to determine the bitumen content as per ASTM 2172 [10]. The Table-5 shows the result for the bitumen extraction value. After the test bitumen content value comes out to be 1% for the recycled aggregate.

**Table: 5: Result of Bitumen Content Test in Recycled Aggregate**

| Weight of sample ( before test ) 1000 gm |
|---|
| Weight of sample ( after test ) 980 gm |
| Bitumen content(20/1000) 100 = 2 % |

Specific gravity is defined as the ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, or, equivalently, the ratio of the masses of equal volumes of the two substances. The specific gravity of solid is frequently required for computation of several quantities such as void ratio, degree of saturation, unit weight of solids and unit weights of soil in various states. It is determined using a Pycnometer bottle. Test is done as per [11]. The results for the specific gravity of the different materials used in the present study are presented in Table-6. The value of specific gravity of these materials varies between 2.52 to 2.73, which is acceptable range for using the aggregates for road pavement construction.

**Table-6: Specific Gravity of Different Grade of Aggregate**

| Type of material | Specific gravity |
|---|---|
| Recycled aggregate 20 mm | 2.53 |
| Fresh aggregate 20mm | 2.72 |
| Fresh aggregate 40mm | 2.62 |
| Fresh aggregate 10mm | 2.65 |
| Stone dust | 2.60 |

The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For construction of base course, bituminous courses and cement concrete, the presence of flaky and elongated particles are considered undesirable as these cause inherent weakness with possibilities of breaking down under heavy loads. This necessitates the evaluation of flakiness and elongation index for aggregate to be used in the construction of pavements. This test is explained as per [12]. The result from the test are given below which is in the acceptable range. Elongation index = 15 % for fresh aggregate, Elongation index = 12.5 % for recycled aggregate.

### B. Mix design of GSB

Mix design of GSB with different types of materials is prepared. One sample is prepared using 20 mm fresh aggregates and second sample is prepared using 20 mm recycled aggregates. The mix design is done by analytical method and presented in graphical form in Fig. 1 for recycled aggregate. In figure upper and lower line show the upper and lower limit of the adopted value and middle yellow line show the adopted value for GSB in recycled and fresh aggregate.

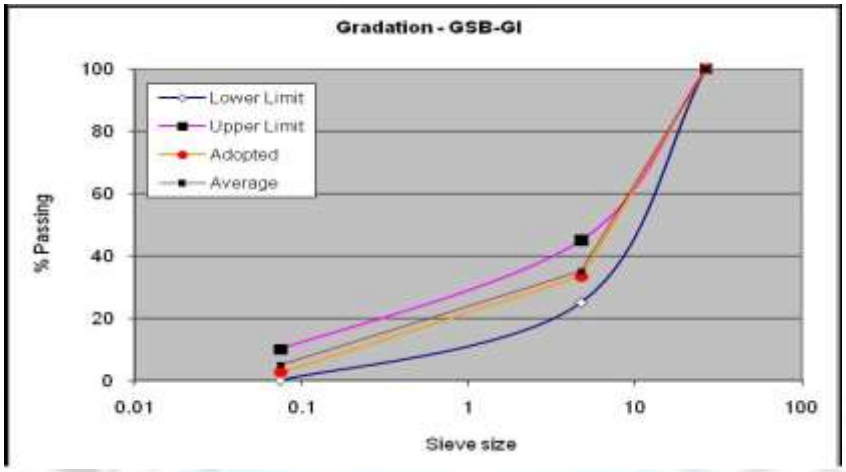


**Fig. 1. Mix Design of GSB with Recycled Aggregate**

The mix design is done by analytical method and presented in graphical form in Fig. 2 for fresh aggregate. In figure upper and lower line show the upper and lower limit of the adopted value and middle yellow line show the adopted value for GSB in recycled and fresh aggregate.

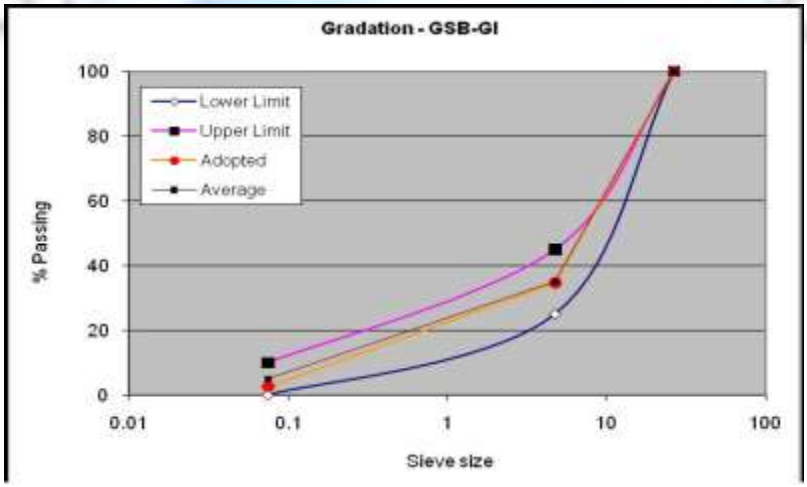


**Fig. 2: Mix Design of GSB with Fresh Aggregate**

### C. Tests on GSB

#### Maximum dry density and optimum moisture content of GSB mix

Standard Procter compaction test is used to determine the optimum moisture content and maximum dry density as per [10] for different materials as shown in Fig. 3 for GSB with fresh aggregates. The maximum MDD in case of fresh aggregate is 2.06 and OMC is 9%.

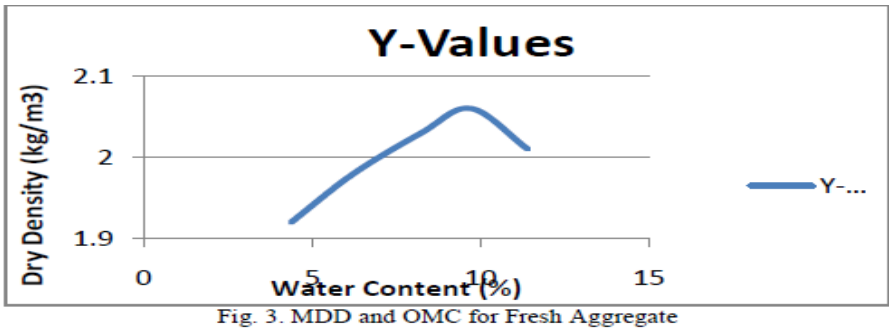

Fig. 3. MDD and OMC for Fresh Aggregate

Standard Procter compaction test is used to determine the optimum moisture content and maximum dry density as per [10] for different materials as shown in Fig. 4 for GSB with recycled aggregates. In case of recycled aggregate the MDD is 2.04 and OMC is 8%. From tests it is very clear that the maximum dry density and optimum bitumen content with recycled aggregates are very near to the values of fresh aggregates. So the recycled aggregate can comfortably use for road pavement construction.

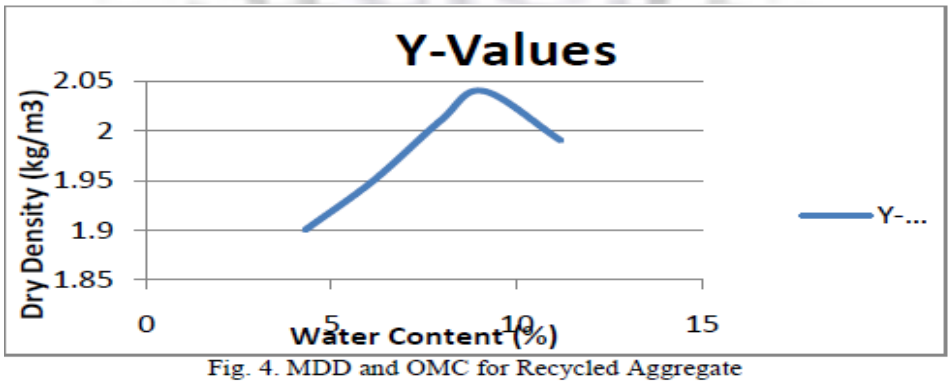

Fig. 4. MDD and OMC for Recycled Aggregate

**California bearing ratio (CBR)**

The CBR test is very important for design of pavement thickness. This test is conducted as per [14]. Result of CBR test on GSB by using fresh and recycled aggregate are presented in graphical form in Fig. 5 and Fig. 6. Sometime a curve with initial upward concavity is obtained, indicating the necessity of correction as for above curve. In this case the corrected origin is established by drawing a tangent from the steepest point on the curve. The load value corresponding to 2.5 and 5.0 mm penetration values from the corrected origin are noted.

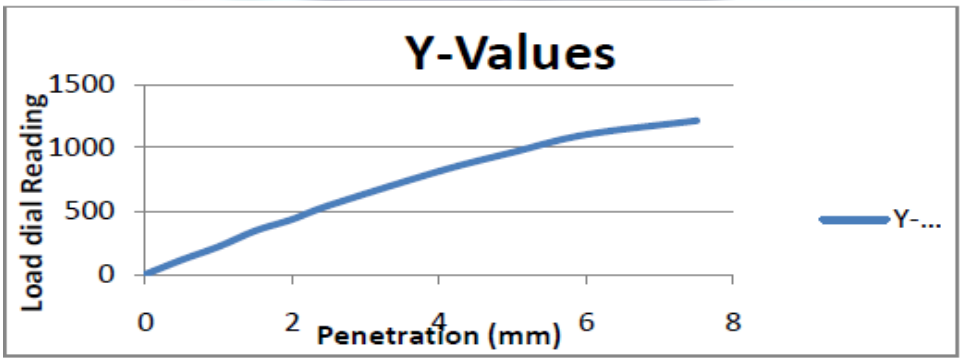

Fig. 5. CBR Curve for Fresh Aggregate

Result of CBR test on GSB by using recycled aggregate are presented in graphical form in Fig. 6.From the curves it may be noted that the CBR value for GSB with recycled aggregates are slightly less than the value with fresh aggregates.

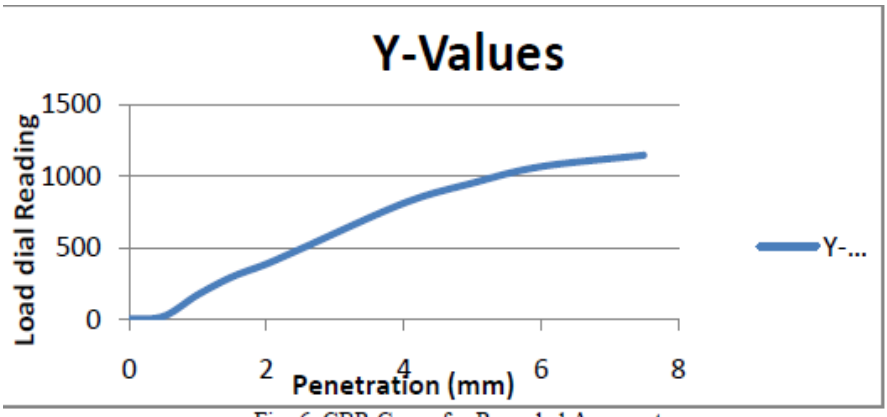

Fig. 6. CBR Curve for Recycled Aggregate

**Permeability test**

The permeability test is a measure of the rate of the flow of water through soil. The knowledge of the permeability is essential in the solution of many engineering problems involving flow of water through soils. As one of the major function of GSB is to act as drainage layer, its permeability is of considerable importance especially when recycled aggregate is used in the construction of GSB. The coefficient of permeability is reported at 27°C as per [15].

The Table-7 shows the result for permeability for the fresh aggregate in GSB.

**Table-7: GSB with Fresh Aggregate**

| Depth of flow (in minute) |
|---|
| 1st 5 cm 26 minute |
| 2nd 5cm 18minute |

The Table-8 shows the result for permeability for the recycled aggregate in GSB. It conclude that the mix that is prepared with recycled aggregate take more time as compared to fresh aggregate.

**Table-8: GSB with Recycled Aggregate**

| Depth of flow Reading (in minute) |
|---|
| 1st 5 cm 35minute |
| 2nd 5cm 26minute |

## CONCLUSION

The following conclusions are drawn from the present study:

- The test result for GSB by using recycled aggregate, stone dust are found to fulfil the MORTH requirement of gradation, MDD for GSB is found to be 2.06 gm/cc in case of fresh aggregate and 2.04 in case of recycled aggregate. The CBR value of GSB with selected materials is found to be varying from 35 % to 46 %.
- The use of recycled aggregate in road construction in GSB will not only achieving economy in the road projects, but also minimizes mining pollution.
- Maximum dry density is found to be 2.04 gm/cc for GSB and 2.07 gm/cc which is suitable for sub grade

construction of road.

- Specific gravity of recycled aggregate, fresh aggregate and stone dust is found to be varying between 2.50 to 2.72.
- From the impact value test it is found that the strength of recycled aggregate is not much lower than the fresh aggregate. The impact value is found to be 14.85% for fresh aggregate and 13.07% for recycled aggregate.
- The water absorption capacity of recycled aggregate is found to be higher than fresh aggregate. The water absorption of fresh aggregate is 0.55 % and recycled aggregate is 1.0%.
- The bitumen content for recycled aggregate is found to be 2%.
- Recycling aggregate from the demolition projects can save the cost of transporting the material to the land fill, and the cost of disposal.
- The Permeability result shows that in case of WBM the permeability of recycled aggregate is more than the fresh aggregate.

Fresh and recycled aggregate is tested for mandatory aggregate properties i.e. Aggregate Impact value and water absorption, which are of significance from road construction point of view. These properties are within permissible limit for both the recycled aggregate and fresh aggregate. After the test and by comparing the properties we find that it is useful to use the recycled aggregate in place of fresh aggregate. The impact value and specific gravity of the aggregate is almost equal to the fresh aggregate. It is useful if we replace the 50 % recycled aggregate with fresh aggregate. GSB mixes with fresh and recycled aggregate satisfy the CBR requirement also. Thus satisfying the fundamental requirement of using the recycled aggregate in GSB mixes.

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