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Characteristic Analysis on Materials for Recycled Composite Pavement

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***Abstract* -The rural and semi urban collector and local streets of India is usually unpaved or paved using the materials such as clay compacted, gravel compacted or water bound macadam surfacing. These materials undergo damages very soon under heavy loadings, extreme weather conditions etc. So it is proposed to adopt composite pavement for paving the local and collector streets of rural areas.**

A composite structure is defined as multi-layer structure where there is a flexible layer over a rigid layer. In a composite pavement, a cement treated base is provided under the wearing course. Due to its unique structural behavior, it got a longer life and provides rider comfort, comparatively greater than any conventional pavement.

But constructing a composite pavement with conventional material is quite expensive. Due to the abundance availability of construction waste and demolition debris, it is proposed to use it, in place of conventional materials.

The broken brick bats are tested for its suitability to be used as a granular sub-base material. For recycled lean concrete to be used as cement treated base course, the crushed concrete is tested for its replacement for conventional coarse aggregate.

The materials of Brick bats for granular sub-base and recycled lean concrete for base course, confines the properties of requirements for pavement materials as specified by Rural road quality control handbook of Ministry of Rural development, Government of India and IRC 63, Use of low grade aggregates and soil-aggregate mixtures in road pavements.

The structural design of composite pavement is done accordance to "pavement design manual" published by "Illinois Department of Transportation".

1. INTRODUCTION

Transportation agencies and road building industry have traditionally designed and constructed two pavement types, namely Flexible and Rigid pavements.

A composite pavement structure is defined as multi-layer structure where there is flexible layer over a rigid layer. The flexible layer provide smooth, safe, and quiet driving surface, where as rigid layer provides a stiff, strong base. In composite structure stiffness of the base is greater than the surface. Composite pavement is also known as semi-rigid pavement.

2. OBJECTIVE

The objective of the project was to test the construction waste and demolition debris for their use in recycled composite pavement. The brick bats generated from the demolition debris were tested for its use in granular sub base layer. In lean concrete cement treated base conventional coarse aggregate is replaced by crushed concrete obtained from building demolition. The recycled lean concrete was tested for its properties to be used in cement treated base.

3. REVIEW OF LITERATURES:

3.1. Structure of Recycyled Composite Pavement

Recycled composite pavement is a composite pavement system comprising of a granular sub-base layer and Cement treated base layer. The Granular Sub Base layer is laid with broken brick bats obtained from demolition debris. The recycled lean concrete is laid as the Cement treated base layer. The recycled lean concrete has crushed concrete obtained from demolition debris as Coarse aggregate.

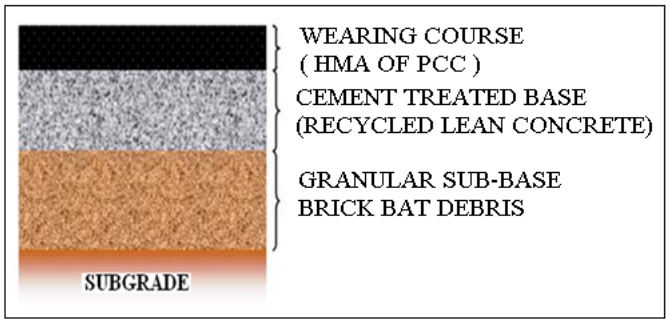


Fig. 1. Structure of recycled composite pavements

3.2. Unpaved Road Statistics In India

1. Length of poorly surfaced roads in India (mud compacted, gravel compacted and water bound Macadam roads) is 1579 kms
2. Length of un-surfaced roads but in motorable condition is 1784 kms Length of un-surfaced roads but not in motorable condition is 285 kms.

3. Further, the roads which is poorly surfaced requires frequent maintenance and frequent overlays when it get damaged, which involves a high cost. But these roads cannot provide a comfortable access to its users.

4. Thus, in order to provide a comfortably accessible road, with low material cost, with low maintenance cost, a composite pavement system where recycled and marginal materials are used is proposed.

3.3. Advantages Of Recycled Composite Pavement

1. Longer life of pavement than other conventional rural paving technique.

2. This is a better technique to pave the rural pavements, with less construction and maintenance cost.

3. Effective usage of construction and demolition debris, which is considered it as a major municipal solid waste.

4. Easy renewal of wearing course

5. Fatigue cracking does not occur in this type of paving technique.

6. Pavement failures such as rutting of wearing course of pavement, pumping of sub-base materials to wearing course, formation of pot-holes are avoided in this type of pavement.

7. Strong support to the flexible layer provided by the rigid base layer.

8. Good levels of readability of the pavement and driver comfort by providing a smooth and quiet driving surface.

9. Adequate pavement surface friction property is provided in this type of pavement.

10. Preservation of structural integrity of the rigid base provided by an asphalt surface layer, which can be periodically replaced.

11. Prevention of the intrusion of deicing salts and surface water to the rigid base due to the protection provided by the asphalt layer.

12. Reduction of the temperature gradient in the rigid layer because of the insulation provided by the overlaying asphalt surface layer.

3.4. Structural Behaviour Of Composite Pavement

In Pavements, the critical tensile strain induces at the soffit of the bounded layer of the pavement. In conventional pavements, there is only one layer of bounded material (PCC of HMA). But in case of a composite pavement there are two layers of bounded materials (cement treated base and wearing course).

On applied load, the critical tensile strain acts as a plastic hinge. When load is applied, the hinge closes. When it is removed, the hinge opens. When this process continued, crack starts propagating from soffit to surface of pavement. When the magnitude of tensile stress created due to wheel load is equal to the magnitude of critical tensile strain the pavement fails.

Thus in composite pavement, the depth required for propagation of crack is greater than that in conventional one. Thus life of the pavement is improved.

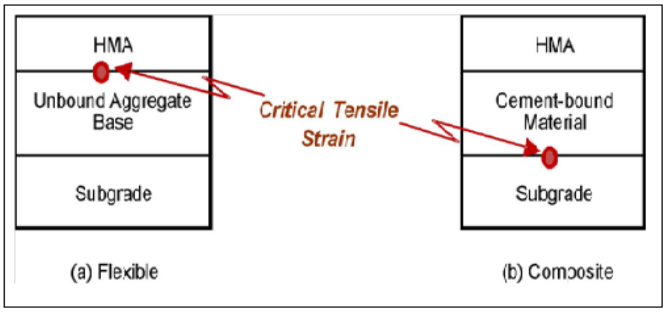


Fig 2. Structural behavior of composite pavements

3.5. AVAILABILITY OF DEMOLITION DEBRIS IN INDIA

It is estimated that waste generation during construction is 40-60 kg per m2, waste generation during repair and renovation is 40-50 kg per m2, Demolition waste ranges form 300-600 kg per m2.

Table 1: Generation of construction and Demolition waste in Chennai City

CONSTITUENT	QUANTITY GENERATED (In million tonnes per annum)
Soil, Sand and gravel	4.20 to 5.14
Brick masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.3 tonnes
Wood	0.25 to 0.3 tonnes
Others	0.1 to 0.15 tonnes

4. SUITABLITY OF BRICK BATS AS GRANULAR SUB-BASE MATERIAL

(Inferred from tests done in accordance with rural road quality handbook, Ministry of rural development, Govt. of India)

Brick bats compacted at maximum proctor density in optimum moisture content can be suitably used as a granular sub-base materials based on the following experimental results.

1. Brick bats are safe against flowing, shrinkage and swelling due to environmental and other factors, which is revealed by testing its Atterberg limits.

2. Brick bats are safe to bear loads and stresses due to the imposed traffic in the pavement. The California bearing ratio of brick bats compacted at 100% proctor density in optimum moisture content, are soaked for 96 hours, got a CBR value of 22%, which is safe for a granular sub-base layer for village roads, where the traffic is lesser than 200 commercial vehicles per day, and the axle wheel load is lesser than 8 tonnes.

3. Granular sub-base layer should consists of material of specified size ranges, in order to ensure the stability, interlocking and bonding between the granular sub-base particles. Once the brick bats are compacted at maximum proctor density at optimum moisture content, the sieve analysis of particles satisfied the specified gradation requirements for a GSB layer.

4. The aggregate impact value of brick bats is in the margin of safety. When the GSB layer is compacted at maximum proctor density in optimum moisture content, the GSB material is subjected to severe impact, and they form as a bed of supporting layer for all other overlaying layers. Since GSB is only a supporting course of cement treated sub-base in a composite pavement, the GSB layer will not experience much impact due to traffic loading.

5. The aggregate have better soundness property against chemical reaction, as it behaved within the specified limits when tested with Sodium sulphate and magnesium sulphate solution of prescribed concentration,

6. The brick bats are free from flaky particles too, which plays a important role in stability of GSB layer.

5. SUITABLITY OF CRUSHED CONCRETE AS COARSE AGGREGATE FOR RECYCLED LEAN CONCERTE

(Tested according to IRC:SP 49 Lean concrete for cement treated sub-base)

1. The water absorption of the crushed concrete is found to be in the specified limits. Hence, the concrete is safe from the hazard of water entrapment. If water entraps into concrete, it disturbs the bond between the materials of concrete, which leads to the instability and failure of the cement treated base.

2. The specific gravity of the crushed concrete is found, and it is more or less similar to that of a conventional coarse aggregate.

3. Crushed concrete has more impact strength than conventional coarse aggregates. Hence the cement treated base of the pavement, casted using crushed concrete can with stand high impacts created due to the wheel loads, imposed in the pavement.

4. Very less fraction of flaky aggregate particles is found to occur. Flaky particles is not preferred for cement treated base, because they likely to get crushed easily. Crushing disturbs the compaction of the cement treated base, and hence the whole layer loses its stability. Since the crushed concrete is mostly free from flaky particles, the cement treated base casted using the crushed concrete is stable enough to with stand the loads.

6. MIX DESIGN OF LEAN CONCRETE: MIX PROPORTION OF RECYCLED LEAN CONCRETE

(Done according to IS 10262 – 2009)

The following mix proportion was adopted in mixing $1m^3$ of lean concrete.

Weight of cement = 327 kg/m3
Weight of fine aggregates = 807 kg/m3
Weight of coarse aggregates = 1130 kg/m3
Volume of water = 196 litres.

6.1. Effect Of Water Absorbtion Property Of Crushed Concrete

Crushed concrete has more water absorption property than conventional BG metal aggregates. So they absorb the water which is used for mixing of concrete. Hence, mixing becomes difficult. Due to poor mix, honey combs are formed on the surface of the concrete. Also it results in low compressive strength of concrete than prescribed (<10.5 MPa in 7-days)

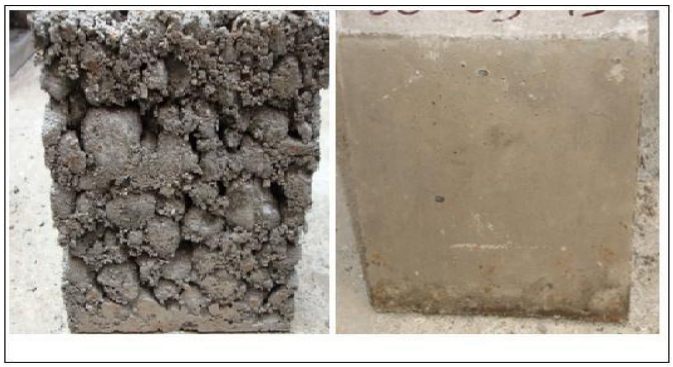
6.2. Treatment Of Coarse Aggregate

Initially, the crushed concrete is added with water, little more than its water absorption capacity. The crushed concrete is well mixed with added water. Thus the voids of cement plaster get filled up with water. The cement plaster is responsible for the greater water absorption property of aggregates.

Further soaking of aggregates in water, makes the cement plaster to get peeled off. The aggregate are surface dried, so that, the water cement ratio in the concrete will not get altered.

The resultant mixture of concrete got good texture. A workable mix of slump of order of 60mm is produced. Due to good bonding between the materials, the compressive strength is also greater than the prescribed limits.

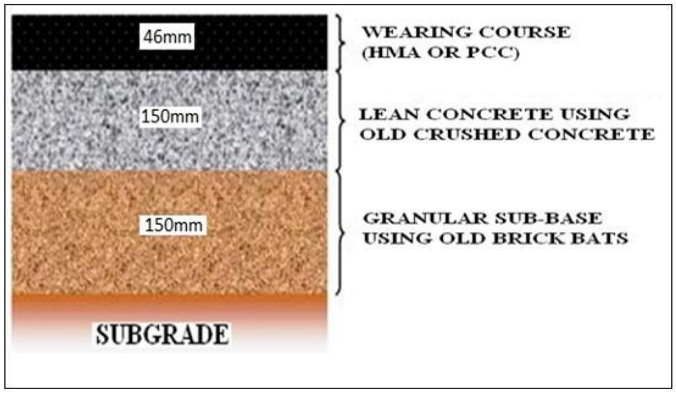
Hence, recycled lean concrete, where treated crushed concrete is used as coarse aggregate, can be effectively used as a cement treated base in a recycled concrete pavement.



Surface of concrete with untreated vs Treated coarse aggregates

7. STRUCTURAL DESIGN OF RECYCLED COMPOSITE PAVEMENT

For performing structural design of recycled composite pavement, the design recommendations specified by, Illinois department of Transportation is followed.
The minimum thickness of pavement structure is designed for traffic factor of CLASS IV roads, for Indian Rural roads. The pavement structure is design to serve a traffic of 88% of personal vehicles (cars and two wheelers), 9% of single unit vehicles (buses and commercial trucks), 3% of multi unit vehicles.



The pavement structure can be adopted, when the CBR of the road bed soil is greater than 10%.

8. RECOMMENDATIONS ON MATERIAL HANDLING

1. When a building is demolished, information is given to local PWD authorities so that they could collect materials from the demolition site as brick bats and concrete debris separately. The concrete debris can also be collected from RMC plants, testing laboratories etc. where ever they are abundantly available.

2. The collected materials shall be taken to a processing and storage yard. These yards may be constructed at every district, so that the materials required for paving the recycled composite pavement in the district is supplied from the corresponding yard.

3. The brick bats shall be broken into particle size in order that maximum portion of materials passes through 23.5mm sieve and retained in 19mm sieve and stored for supply.

4. The concrete shall be crushed into particle size in order that maximum portion of materials passes through 19mm sieve and retained in 12.5mm sieve. The crushed concrete shall be soaked in water for 48 hours, surface dried and stored, so that they could get free form dust, plasters and other unwanted particles.

5. The brick aggregates shall be transported in batches, for each batch the optimum moisture content is determined. The crushed concrete shall also be transported in batches for which the specific gravity and water absorption for each batch is determined.

6. The brick bats is spread for a thickness not exceeding 100mm, either manually or mechanically, if 60 – 80 KN smooth wheeled roller is used. Before rolling, the water corresponding to optimum moisture content of the batch, is added and then compacted. Thus the granular sub-base layer achieves maximum dry density.
7. A mix design is made for lean concrete, according to the specific gravity of crushed aggregates of the corresponding batch. The aggregate shall be added with water, corresponding the to the water absorption of the batch and well mixed in such a way that, the wetness of crushed concrete shall not alter the water cement ratio of the mix.

8. The lean concrete is then mixed and the slump should be in the order of 25mm to 75mm.

9. CONCLUSION:

In a recycled composite pavement, brick bat debris is suitable for granular sub-base layer compacted to maximum dry density in optimum moisture content, since it is stable against all the possible effects, which may tend to act in the pavement. The crushed concrete can be effectively replace the conventional coarse aggregate, in a lean concrete cement treated base. The crushed has similar properties of conventional Granite metal. The recycled lean concrete is casted using crushed concrete as coarse concrete as coarse aggregate and reduced cement content. The coarse aggregate has to be initially wetted with water, corresponding to water absorption capacity.

The recycled lean concrete is casted using crushed concrete as coarse aggregate and reduced cement content. The coarse aggregate has to be initially wetted with water, corresponding to water absorption capacity, to achieve the stipulated workability and required compressive strength. Wearing course can be laid of both, Plain Cement Concrete or Hot Mix Asphalt and choice of wearing course is based upon the material availability, choice of the user etc. Thus a recycled composite pavement, acts as a effective, long life solution for Unpaved Indian rural roads, since low laying and maintenance cost is involved in it.

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