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Experimental Analysis of Pavement Construction using Recycled Concrete Materials

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Abstract: In highway engineering, subbase is the layer of aggregate material laid on the subgrade, on which the base course layer is located. It may be omitted when there will be only foot traffic on the pavement, but it is necessary for surfaces used by vehicles. Subbase is often the main load-bearing layer of the pavement. Its role is to spread the load evenly over the subgrade. The materials used may be either unbound granular, or cement-bound. The quality of subbase is very important for the useful life of the road.

Unbound granular materials are usually crushed stone, crushed slag or concrete, or slate. Low quality subbase material should not be accepted, including large pieces of rock and concrete.

Pavement Transport is vital to India's economy. It enables the country's transportation sector contribute 4.7 percent of India's gross domestic product, in comparison to railways that contributed 1 percent, in 2009-2010, despite railways handling of passenger and pure cargo. Pavement transport has gained in importance over the years despite significant barriers and inefficiencies in inter-state freight and passenger movement compared to railways and air. The government of India considers pavement network as critical to the country's development, social integration and security needs of the country. India's pavement network carries over 65 percent of its freight and about 85 percent of passenger traffic. Indian pavement network is administered by various government authorities, given India's federal form of government.

Keywords: Construction, Recycled Aggregate, pavements.

INTRODUCTION

Cement-bound materials come in multiple types. Mass concrete is used where exceptional loads are expected, with thickness usually 100-150 mm, and optional reinforcement with steel mesh or polymer fibers. Other cement bound materials (CBM), with less strength but also lower cost, are used. They are rated by strength, from the weakest CBM 1 (also formerly known as soil cement) through CBM 2 to CBM 3, 4, and 5, which are more similar to concrete and are called "lean mix".

The thickness of subbase can range from 75-100 mm for garden paths through 100-150 mm for driveways and public footpaths, to 150-225 mm for heavy used roads, and more for highways.

The emergence of recycled material as a viable product in pavement construction introduces an opportunity for councils to manage the future cost of road pavement maintenance and construction. Recycled crushed concrete, rock, stone, asphalt, brick and glass fines now compete with traditional virgin aggregate and sand extracted from quarries, on criteria of quality, price and availability, while offering many long term environmental benefits associated with using recycled product. Reports of quarry material price increases of up to 70% in New South Wales, due to shortages of quarry material near Sydney, have sparked concern that the Victorian market could face similar increases. In Victoria, viable locations for future quarries are becoming increasingly constrained as regional development moves into areas of known virgin resources. Continued demand for pavement materials will inevitably exhaust the supply for existing quarries, forcing the supply of Victorian quarry resources to move further away from demand – much like the circumstances in New South Wales where the increased cost of haulage greatly impacted prices for virgin materials. This business case presents the competitiveness of local recycled materials as a supplement for traditional quarry materials in road pavement. Recommendations for councils to procure local recycled materials for road pavement construction are also provided.

Recycled materials perform as well as traditional quarry materials

VicRoads specifications for application of recycled pavement materials are developed through robust scientific testing and trials. This ensures that their use is in appropriate low risk sub base and that VicRoads accredited recycled products are of excellent quality and performance.

False perceptions, about the quality of recycled materials, exist at the local government level (and beyond) and need to be overcome in order for recycled materials to compete fairly.

The pavement classification number (PCN) is an International Civil Aviation Organisation standard used in combination with the aircraft classification number (ACN) to indicate the strength of a runway, taxiway or airport apron (or ramp). This helps to ensure that the airport ramp is not subjected to excessive wear and tear, thus prolonging its life.

Although important for the runway the major use of this number is for the apron. On landing the aircraft is light on fuel and usually less than 5% of the weight of the aircraft touches the runway in one go. On takeoff the aircraft is heavy but as the aircraft accelerates the weight gradually moves from the wheels to the wings. It is while the aircraft is being loaded and taxiing prior to departure, that the apron experiences significant loads from aircraft weight.

Typically this is only used for asphalt or concrete runways and would not be used for grass or gravel.

Construction of Base/ Sub-base

A base/ sub-base to the concrete pavement provides uniform and reasonably firm support, prevents mud-pumping , and acts as capillary cut-off. Sub-base for concrete pavement could be constituted with brick flat soling, WBM, granular aggregates, crushed concrete, slag, stabilized soil etc. As per IRC:15 (2002), sub-base could be of three types with (i) Granular material (for example, brick soling with one layer of sand under it, WBM, well graded granular materials etc.) (ii) Stabilized soil (iii) Semi-rigid material, (for example, lime burnt clay puzzolana concrete, lime fly-ash concrete, lean cement concrete roller compacted concrete etc.). Following contains a brief discussion on dry lean cement (DLC) concrete as sub-base, which is popularly being adopted for the current concrete pavement construction in India.

Dry lean cement concrete as sub-base

The thickness of DLC, generally recommended is 100mm or 150mm (IRC:SP-49 1998). The maximum aggregate to cement ratio is 15:1. The average compressive strength of DLC cubes at 7 days, as recommended by Indian guidelines

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(IRC:SP-49 1998) should not be less than 10 MPa, tested on 5 samples and individual compressive strength should not be less than 7.5 MPa, at 7 days (MORT&H 2001, IRC:SP-49 1998).

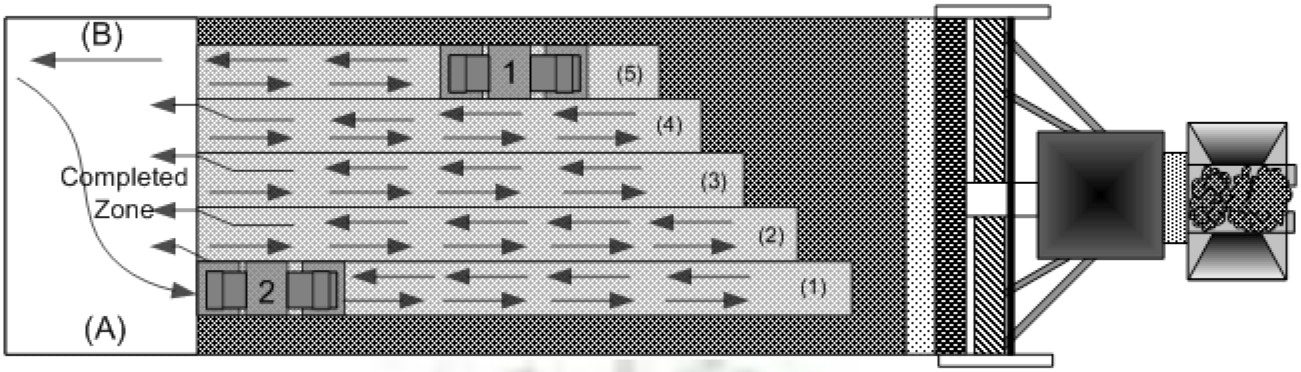

Fig. 1: Compaction sequence for DLC (A) is the outer edge, and (B) is the inner edge of the pavement

Fig. 2: Laying of DLC of the recycled concrete

Before construction of DLC sub-base, the prepared subgrade is sprinkled with water to moisten the surface. The material is to be laid uniformly by a paver without any segregation . The paving machine should have high amplitude paving bars. The curing of DLC can be done by spraying liquid curing compound, or by covering the surface by gunny bags. As per Indian guidelines, the construction of cement concrete pavement can only start after 7 days of DLC construction.

Using crushed concrete as aggregate conserves resources and eliminates disposal costs

Breaking up an old concrete pavement and reusing it as a g g regate is a cost-effective option for reconstructing deteriorated pavements. Recycling eliminates disposal problems and tipping fees. In urban areas where landfill space is scarce, dumping concrete is difficult and costly. The cost of recycling concrete pavements only includes the cost of c rushing. Costs for aggregate hauling and concrete disposal are eliminated. In some areas, the supply of acceptable natural aggregates is dwindling. Reusing existing material is helpful where quality supplies are scarce. A new concrete mix can contain up to

100% recycled coarse aggregate, and re c y c l e d fines can replace 10% to 15% of virgin sand. Recycled aggregate also can be used in concrete shoulders, median barriers, and granular and lean concrete base layers. Fine aggregate also makes good fill for subgrade corrections .

Recycling operations

The existence of reinforcement in concrete pavement is no longer a limitation to recycling. Advancements in crushing equipment and techniques allow doweled, mesh-reinforced, and continuously reinforced pavements to be recycled. The goal of recycling concrete pavement is to maximize pro d u ction of coarse aggregate. The coarse aggregates are more valuable and more usable than fines. A contractor has many choices of recycling equipment and processes , each affecting the yield of coarse agg regate. The key steps in re cycling portland cement concrete pavements are preparation, bre a king, concrete removal, steel separation, and crushing .

Pavement preparation

The first step is to remove joint sealant, shoulders, asphalt patches or overlays, and anything else that may contaminate the recycled aggregate. Typically, front-end loaders are used to remove joint sealants (with a metal tooth that rakes out the sealant), scrape off asphalt overlays, or pick up loose material after milling. The loader can dislodge any material still adhering to the old concrete surface. Bro o m i n g removes most loose particles. Asphalt shoulder removal should p recede breaking operations on rec o n s t ruction projects. Removing the shoulders takes away lateral support on the slab, which eases portland cement concrete (PCC) pavement breaking and removal.

Pavement breaking

Breaking shatters concrete for ease of handling, and debonds concrete and reinforcing steel. Heavier breakers can rupture steel wire mesh. Typically, breaking machines are classified as impact and resonant. Diesel hammer and drop weight devices operate at 90 blows per minute, and break rubble into pieces 18 to 24 inches across. Resonant devices deliver more than 2,600 vibrations per minute and tend to form pieces about 6 inches across. Several factors affect the production rate of breaking equipment. M o re impact energy is needed with greater slab thickness, concrete strength, and quantity of reinforcing steel. As base support inc reases, less impact energy is needed to effectively break the concrete pavement.

New pavement Construction Using recycled aggregates or concrete

No special techniques are necessary for constructing a new conc rete pavement made with recycled aggregate. These projects can meet the same quality standards as those using virgin materials. The workability of a concrete mix depends on the amount and characteristics of the recycled fines. Mixes with a large quantity of recycled fines can be harsh and difficult to finish due to their angularity and high absorption rate. Using natural sand in the concrete mix will minimize these problems. Recycled coarse aggregate produces little variation in concrete workability. In some cases, pavements are built in two courses. The slab design has a bottom layer of concrete using recycled aggregates and an upper slab portion using high-quality virgin material. The design requires an upper layer thickness of about 11 ⁄2 inch. A modified slipform paver or spreader places the lower layer of recycled-aggregate concrete, then a slipform paver places the h i g h-quality concrete upper layer. The base course is still wet during placement of the top course. After consolidation and curing, the two courses become a monolithic slab.

Recycled aggregate meeting the requirements for virgin aggregate can be included in the concrete mix or used in base courses. Typically, the contractor decides how to best use the material. The most common application is for base course. The cost of using re c ycled aggregates for base material includes only the cost of cru shing operations. Breaking, removal, steel separation, and transportation costs are incidental. When using recycled aggregate in concrete, no special handling, batching, or mixing pro c e d u res are necessary. However, the high absorption of recycled aggregate may make it necessary to add more water and start with a higher slump. Dry recycled aggregate continues to absorb mix water after mixing in the batch plant. This results in less workability and a lower slump at the paving site. Some contractors use sprinklers to keep recycled aggregate stockpiles moist.

Conclusion

Compressive strengths of recycled-aggregate concrete are similar to those for virgin aggregate concrete. For mixes containing recycled fines, expect some minor strength reductions. This is because natural sand particles are stronger than recycled fine aggregates. The majority of the strength loss is from material smaller than 0.08 inch. Flexural strength of concrete with recycled coarse aggregate might be slightly lower than a similar mix with virgin aggregate usually no more than 10% when natural sand is used. Using recycled fine aggregate in the mix might reduce flexural strength 10% to 20%.

The water absorption of concrete depends on the quantity of recycled aggregate. The amount of absorbed water is proportionally increased with increasing recycled aggregate content. Water absorption depends on the porosity of cement matrix in the new concrete and porosity of cement matrix of the recycled concrete: if recycled aggregate is produced from low porosity waste concrete, water absorption of the new concrete depends on the achieved structure of the new cement matrix. Wear resistance of the concrete depends on the amount of recycled aggregate. Concrete wear resistance decreases with increasing recycled aggregate content, due to the increased quantity of hardened cement paste, which wears easier than grains of natural aggregate.

If a pavement exhibits alkali-silica reactivity, evaluate and test a mix before deciding to recycle the pavement. Avoid including recycled alkali-silica material as an aggregate if virgin material is readily available. In aggregate-scarce locations, it may be important to investigate using the material.

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