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A review on analysis of characteristics behavior of locally existing material in pavement sub base

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ABSTRACT

Base materials that meet specifications are getting more difficult to get in many regions of the United States. As a result, higher quality materials have to be hauled long distances. This act would significantly increase the costs associated with roadway construction and subsequent maintenance and rehabilitation. Low quality or out-of-specification materials are usually available from local sources. If through appropriate treatment of the materials or/and structural design, the optimum use of local materials can be permitted, the construction can be accelerated and significant monetary benefits can be realized Most of the pavement design guidelines are based on the assumption that aggregates are important ingredients of the pavement structure. However, availability of good quality aggregates may be a constraint in some locations. To transport good quality aggregates from a long distance may not be economically feasible. Due to the excessive investment and maintenance cost, new methods of design had to be sought and new building materials are introduced. Some researchers tried with soil, which is available everywhere. The engineering properties of soil were modified using certain treatment. At the same time, various waste products are created by several industrial plants. These waste products could be used in the road construction projects after following certain treatment procedure. By treating natural soil or fly-ash, or by addition of certain materials to it, new road construction Each highway was divided into three sections with different materials in the subbase and base layers, such as fine lateritic soil, fine lateritic soil stabilized with lime, and a mixture of fine lateritic soil and crushed rock. The compaction characteristics were evaluated in laboratory tests. From the time the segments were constructed (in 1998 and 2000) until 2001, the stress-strain behavior of the paving structures was evaluated by in situ tests, such as the plate-bearing, Benkelman beam, and falling weight deflect to meter tests. From the results, conclusions were drawn about which of the chosen materials showed the best performance in mechanical behavior.

Keyword: *Pavement sub base, Road construction, Material specifications.*

1. INTRODUCTION

The performance of sub base depends on many factors such as structural adequacy of the pavements, properties of materials used, traffic loading, climatic conditions and construction practices. Previous research has found that much of the distress experienced in flexible pavements can be traced to the problems encountered in base materials. Normally, the use of high-quality base materials is required for pavement construction and rehabilitation to comply with the standard specifications. However, the reserves of high-quality materials are diminishing in some regions and the long-distance hauled-in materials would result in high transportation costs. This situation has required the use of local sources of base materials in pavement construction.

Local materials may be out-of-specification with respect to the standard specifications for roadway base/Subbase. Under many current standard specifications, a base material can be considered out-of-specification for a variety of reasons (inadequate gradation, inadequate plasticity, inadequate strength etc.). In many cases, local base supplies miss these specifications by a small margin. Since the criteria set in the current specifications are experienced-based, some of the parameters used to classify base materials may be less significant than others. With appropriate treatment or structural design, many of these out-of-specification materials can perform adequately for low-volume roads. These materials should be capable of providing low-cost base and subbase in roads that are subjected to low traffic levels but high axle loads. Studies conducted by the UK Department for International Development (DFID) and others have shown that, with appropriate design, the use of local materials can play a crucial role in terms of cost saving, pavement performance, resource management and environment protection. Traditionally, the materials which are used in highway construction are also used in other construction activities (like buildings, industrial set ups, dams, power houses etc.). Aggregates for base and sub-base use are composed of Steel slag, Moorum sand, crushed aggregates, gravels or natural materials that provide the necessary strength and durability. To meet the enormous demands of construction the above natural aggregate resources are heavily consumed for the construction of roads, especially in urban markets. The extraction of aggregates from hills through quarrying operations, crushing and transportation etc. are not only responsible for the environmental degradation in the form of loss of forest lands, vibrations, dust, noise, pollution hazards etc. but also consume a large amount of energy-depleting the energy sources.[Indian Highways, May 2011].

The generation of a vast quantity of waste materials from industries like iron, steel, coal, etc. is causing a shortage of dumping space and creating severe environmental pollution. Solid waste generation from steel industries such as power plant fly ash, acid sludge from by-product plant, tar sludge, B.F. slag, steel slag, coke breeze, calcined lime, dolomite dust and steel scrap etc. are generated in vast quantities causing environmental degradation. [Viswanathan & Gangadharan (1996)].

1.1 Locally existing materials

Industrial wastes or by-products, locally available materials can be used to partially replace the natural aggregates in base or sub-base application, which are not used for other construction purposes but available in huge quantities at a nominal cost. These materials, may not match the desired standards or specifications but provide a prospect for their optimal utilization in road construction. Use of the above materials may result in a decrease in the construction cost of roads, satisfying the quality requirements and could also help in improving the strength and durability of the pavement. In the present work slag from steel plant industries and locally available hard moorum are used as non-conventional materials in road base and sub-bases.

1.2.1. Slag from steel plant industries

India is now the fourth largest crude steel producer in the world contributing pig iron, sponge iron, alloy and non-alloy steel. Slag is a by-product generated during the manufacturing of pig iron and steel. During the process of pig iron making (in the blast furnace) and steel production (in steel melting shop), slag is produced by the action of fluxes upon gangue materials within the iron ore. The slag primarily consists of silicon, calcium, aluminum, iron, magnesium, and manganese in various combinations. Under controlled cooling, slag becomes hard and dense, which can achieve the required strength to sustain heavy loads making it especially suitable for use in road construction. [Indian Mining Yearbook-2011].

Present Utilization Trends in India:

Iron and steel industry slag, either granulated or crystalline, is considered as a prominent and a useful raw material for developing of modern construction materials. The slag generated from different steel making processes, once treated as a useless waste but is accepted now and often, preferred and specified, as it is known to be an important material with a wide spectrum of usage, as investigated by numerous researches worldwide. The properties and composition of iron and steel slag influence its application in civil engineering construction (Dhoble and Ahmed, 2012). A wide range of application of Iron and steel slag has in building and road construction. Some popular applications of iron and steel slag are — as a raw ingredient in cement manufacturing, as aggregates, agricultural fill, glass manufacturing, as a mineral supplement and pH modifiers in soil amendment The amount of steel slag utilization is just about 15 to 20 percent of its generation, thus a huge quantities are still dumped in vicinity occupying a large area of valuable land.

The amount of slag generated is so vast that it produces a dumping problem and can also be hazardous to the environment. So due to the extensive growth of construction and sufficient availability of slag, it can be used as a partial substitute for the natural aggregate materials in road base and sub-base applications. The cost of slag is lower than that of natural aggregate materials, and it is sufficiently available. The slag when used in road sub-base in bounded form, its hazardous effects can be minimized by making it environmentally sheltered. So the above factors can make the use of slag in road base and sub-base layer economic and cost-effective from a construction point of view and also take care of the environmental problems.

2. LITERATURE REVIEW

2.1 Characterization of slag

Basic oxygen furnace (BOF) steel slag is a residue obtained from the basic oxygen converter during steel-making operations. It can be partially used as a construction material for roads. Though it is an attractive construction material, before the application its long-lasting behavior and the related environmental influences should be considered into account. BOF slag is generally composed of silicon, calcium, iron and some potential toxic elements or known as toxic elements, like chromium and vanadium. [P. Chaurand., et al. (2006)].

Fig 2.1 Locally available Steel Slag

2.2 Physical properties of slag and moorum

Slag as a residual or by-product is often utilized in the construction of cementations applications to optimize the utilization of naturally available aggregate materials and conservation of natural resources. Ferrous slags (blast furnace slag, steel making, manufactory, and ferroalloy) are the industrial by-products can be used in pavement construction because of their wide convenience and scope of applications. [J. J. Emery (1982)]. In a European stabilized base layer 60% blast furnace slag (0 to 60 mm), 25% steel slag (0 to 15mm) and 15% granulated blast furnace slag mixture was compacted with 10% water by mass using standard highway equipment that showed excellent results.

Industrial wastes and by-products are also utilized in recycling processes, manufacturing of new products, or as construction materials to minimize their environmental effects. The steel slag aggregate (SSA) was utilized in road construction in Saudi Arabia, which is a by-product of the steel manufacturing process [Saad Ali Aiban (2006)]. Two types of SSA materials were taken: material finer than 5 mm (labeled 0 – 5 mm) and a material having sizes up to 37 mm (labeled 0 – 37 mm). Several gradations were tried taking a mixture of SSA, locally available Moorum, Moorum fines, and sand and the gradation corresponding to the maximum CBR (as per ASTM method) was taken. The CBR value of proposed gradation was found to be 119 at molding moisture content of 5%. In a modified gradation, 10 % SSA fines were added to the proposed gradation gave highest CBR value of 383. Similarly, different percentages of dune sand were added to SSA and compacted at 5 % moisture content. The highest CBR value of 406 was obtained at a sand percentage of 15 %. Locally available Moorum (having maximum CBR value of 224) was used to reduce the consumption of SSA, taking a blend of equal proportions of SSA and Moorum produced CBR values reaching 400. These values were far more than the values presented by pure Moorum of the same gradation.

A field trial was used having:

- A compacted subgrade (comprised of the existing Moorum and mixed with sand in some places).
- A 100 mm thick fine SSA (0-5 mm) filter layer.
- A 200 mm SSA (0–37 mm) base course reconstituted to the modified gradation
- The asphalt concrete layers (a 70 mm thick base layer and a 40 mm thick wearing layer)

The field trial showed an excellent performance over the years even under poor drainage and submerged conditions.

The steel slag combined with limestone aggregates were used in different proportions to achieve desired density and shear strength in Egyptian roads. The grain size distribution, porosity, unit weight, Los Angeles abrasion value, the angle of internal friction, bulk specific gravity, water absorption of steel slag and limestone aggregates were found out. OMC and MDD for various blended mixes were determined; the OMC decreased, and the MDD increased with increase in slag percentage. California bearing ratio and resilient modulus were increased with increase in slag percentage up to 70%. For the blended mix of 70% steel slag percentage to 30% limestone gave highest CBR value (of 370 %) and resilient modulus (of 4000 Mpa). Theoretical analysis of the blended layer was achieved using a finite element (FE) computer programme (FENLAP) estimating the deflection, vertical strain, vertical stress and radial stress [Behiry (2012)].

Fly ash and phosphor-gypsum modified steel slag aggregates were used in road base construction in China [Weiguo Shen., et al. (2009)]. The particle size distribution and apparent density of individual materials were determined. The mixture prepared by blending of materials was stored for 4 hours and then compacted (at optimum moisture content after 1 hour of cement addition) into a 50 mm dia×50 mm height cylinder mould to prepare cylinder specimen. The relative compaction with the MDD was found to be 97%. For Standard Proctor, compaction test and Unconfined Compression Test T0804-94 specifications (China) were followed which are similar to the ASTM codes. The stabilized soil samples were sealed in plastic bags and stored at room temperature and a 95% relative humidity, and then soaked in water for 24 hours (at room temperature) before compressive strength tests. A steel slag to fly ash ratio around 1:1 having a phosphor-gypsum dosage of 2.5% was found to be optimum giving a 7-day strength of 1.86 Mpa and 28-day strength of 8.36 Mpa that meets the requirements (China criteria of semi-rigid road base material).

Basic oxygen furnace (BOF) slag, as well as electric arc furnace (EAF) slag, is also used for road base as well as road base asphalt concrete. In a trial, the mix design and performance characterization of the bituminous mixes was done in Italy. Gyratory compaction tests, indirect tensile strength tests, fatigue tests, permanent deformation tests and stiffness modulus tests (at various temperatures) of the mixtures of EAF slag and asphalt showed better mechanical characteristics than those of the conventional natural aggregate and asphalt mixture, satisfying the acceptable criteria for Italian road construction. [Pasetto and Baldo (2010)]. In a moisture damage investigation of the road, the BOF prepared asphalt mixtures were characterized by resilient modulus tests, indirect tensile strength tests. The freeze-thaw tests showed better moisture sensitivity of BOF slag mixture than that of the basalt mixture [Jun Xie., et al. (2012)].

3. CONCLUSION

- The slag samples are well graded which require less amount of crushed (conventional) aggregates for blending to meet the desired grading for use in different layers of sub-base
- The impact values of the slag, crushed aggregates and wet impact value of moorum are within the maximum limits for road base or sub-base applications
- Cement is used as a binder for stabilization of moorum because of its high plasticity
- The UCS values of the combination of moorum and crushed aggregates specimens layers

4. FUTURE SCOPE

- Various combinations of the materials, like moorum, steel slag etc. can be tried and the mix which gives maximum fatigue life can be obtained.
- Most economical combination of the layer thickness and material properties can be obtained by performing economic analysis.
- Durability test can be performed to ensure the performance of stabilized layer.
- Rutting equation can be developed for bituminous pavement with Sub base.
- The permeability of the slag and crushed aggregate mixture can be determined especially in the drainage layer of the sub-base by using suitable tests.
- The strength parameters considered in the study are CBR and UCS. Apart from these tests, the repeated load triaxial test can also be performed to find out the effect of dynamic loading in different layers, and the realistic resilient modulus values may be determined.

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