A REVIEW STUDY ON THE USE OF COPPER SLAG IN BITUMINOUS CONCRETE MIXES

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Abstract: In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. Instead of using natural aggregates in road and concrete constructions some of the waste industrial by products can be used widely. Many highways agencies, private organizations, and individuals are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability, availability of waste products and performance of using waste industrial produces in highway construction. The main by-product of metallurgical industries is often defined with the general term "slag". Different methods are employed to cool the slag for disposal or use (air, pelletized, foamed, or granulated). The most common metals for slag production are iron, steel, as well as nonferrous metals, like copper and nickel. Furnace steel slag is used in various construction sectors, like the production of cement-based materials (as mineral additive) the improvement of concrete mechanical properties. Another application of steel slag is the removal of some hazardous substances such as ionic copper and ionic lead from waste water. In this research paper, a review study on the use of copper slag in bituminous concrete is done.

Keywords: Bituminous Concrete, Copper slag, Marshall Stability, Flow Value.

1.1 INTRODUCTION

Bituminous concrete is a type of construction material used for paving roads, driveways, and parking lots. It's made from a blend of stone and other forms of aggregate materials joined together by a binding agent. This binding agent is called "bitumen" and is a by-product of petroleum refining. The sustainable or viable management of natural resources enquires the decoupling of economic growth, use of resources and the waste production. Building up road pavement layers involve the use of large quantities of raw materials (cement, asphalt and aggregates), the production of which is associated to energy consumption and to the production of gas pollutants in substantial quantities. On the other hand, in developed and developing countries, the production of industrial waste or byproducts is essential. Recycling and re-use of these materials can decrease the environmental impacts from the excavation and treatment of raw material. The application of sustainable development and management of natural resources leads to an integrated study frame, taking into consideration -apart from the technical cost- the social and environmental cost. The use of alternative products -like scrap tires, reclaimed asphalt, fly ash, iron and steel slags, etc- as aggregates in road construction constitutes a research and application field in European Union (EU) and USA in the context of sustainable development. Especially slag products can be characterized as sustainable materials because they are easily recycled and could be reused in different applications. Valuable natural resources are saved when slags are selected as pavement aggregates while at the same time green house gases are reduced. In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. Instead of using natural aggregates in road and concrete constructions some of the waste industrial by products can be used widely.

1.2 PAVEMENT STRUCTURE

A pavement is a part of the road, subjected to stresses imposed by vehicular loading applied, as well as to deterioration from the effects of weather and the abrading action of moving traffic. A satisfactory pavement design is one that is able to withstand these effects for a required period of time. A pavement consists of a multi-layer system, which is formed of a number of layers of compacted unbound aggregates and/or bound materials. There are three main components of a road pavement; foundation, base and surfacing.

Every one of the layers in an pavement has its own particular capacity, which are discussed below:

1. **Subgrade:**

   Subgrade is not formally a pavement layer. However, its properties and function must be fully understood in order to design and construct a satisfactory pavement over it. Subgrade is the natural soil or made-up ground (fill) on which the pavement is built. The function of the subgrade is to support the load of the whole pavement.

2. **Capping**

   Over a weak subgrade a capping may be provided to act as a subgrade improvement layer. It can also be used as a working platform and prevents deterioration of the subgrade. This layer usually uses a relatively low quality, cheap, locally available aggregate. Some recycled materials are also used as an alternative material to make a capping. Occasionally, a stabilizer such as cement or lime is incorporated into the upper part of the subgrade to improve the strength and bearing capacity of the subgrade soil. The surface of the subgrade or capping layer, where present, i.e. the level on top of which the sub-base is placed is known as the formation.

3. **Sub-base**

   A sub-base is the main structural foundation layer. It must be able to resist the stresses transmitted to it via the road base and also must be stronger than the subgrade soil or capping beneath it. One of its main functions is to act as a platform upon which pavement construction can take place without damage to the subgrade. It also acts as a final load distribution layer and provides a frost-resistant layer.

4. **Base**

A base is the main structural layer of pavement, which provides the major part of the strength and load-distributing properties of the pavement so that the underlying materials are not over-stressed. It is normally designed to be very dense so as to be stiff, spread the loading well and is highly stable so that it resists permanent deformation and fatigue cracking due to repeated loading.

5. **Binder Course**

   The main functions of the binder course layer are to distribute some of the traffic loading and to regulate the underlying layer to provide an even profile on which to lay relatively thin surface course layer.

6. **Wearing Course**

   The wearing course is a uniform carriageway surface upon which vehicles run. It provides the initial load distribution. It also provides a weatherproof finish layer that gives skid-resistance and resistance to polishing and abrasion by traffic, an even running surface and one that will rapidly shed surface water. A good surface course should minimize traffic noise, resist cracking and rutting, protect the underlying road structure and be durable.

1.3 FACTORS THAT IMPACT THE ACHIEVEMENT OF REUSING OF THESE MATERIALS

The relative significance change from nation to nation however commonly incorporates the following:

- The public is becoming more concerned about the environment.
- Lack of virgin aggregates.
- Public opposition to aggregate quarrying.
- Public opposition to land-filling.
- Government policy to minimize the use of natural aggregate and promote the use of recycled materials as alternative aggregates.
- Introduction of aggregate taxes to encourage recycling and utilization of secondary material.
- Introduction of landfill taxation to stimulate waste reduction and re-use.
- Introduction of climate change taxes by government.

1.4 LITERATURE REVIEW ON COPPER SLAG

Mobasher et al. the slag contains some concentration of metals in the ores from which they were produced. Adding copper slag as a replacement of fine aggregates shown to have a significant influence on increasing the stability of bituminous mixes. From the above literature it is observed that copper slag has been used in construction of bituminous pavements. Copper slag has been suggested as a fine aggregate in limited quantities for bituminous mixes but not as an alternative to the aggregate in bituminous mixes. The National

Highway Authority (NHA) was created, in 1991, through an Act of the Parliament, for planning, development, operation, repair and maintenance of National Highways and Strategic Roads specially entrusted to NHA by the Federal Government.

In this research, author classified aggregates according to NHA Class A. It is important to know about pavement distresses before laying any pavement, as in which areas which type of distress can occur. There are various types of asphalt failures each with its own unique classification and repair approaches. Here we have explained some common pavement distresses and their remedies.

K. Arun Kumar et al stated the Characteristics and Utilization of Copper Slag-Fly Ash Mix as Road Construction Material. In this paper, an effort has been created to check the feasibility of copper dross – ash combine to be used in molding course of the versatile pavements. Variety of cylindrical takes a look at specimens (38 millimeter diameter and seventy six millimeter height) was ready with raw materials like copper dross and ash in several proportions. These samples were cured at a temperature of 300C and wetness ratio of eighty fifth during a humidity controlled chamber for various activity amount of zero, 7, fourteen and twenty eight days. The geotechnical properties of various trial mixes, namely, unconfined compressive strength, soaked CBR and tri axial shear strength were determined. The consequences of ash and content and activity amount on the on top of geotechnical properties were investigated. From this study the half-hour ash +70% copper dross combine was found to be optimum to be used in subbase layers of the versatile pavements. Therefore, construction of road pavements utilizing the optimum combine as stated on top of is feasible. This can facilitate in protective the conventional aggregates used for molding and eliminate problems associated with disposal of commercial waste like copper slag and flash.

Kacha et al. The study concluded that all researchers gave their findings with concrete up to 30- 40% replacement of fine aggregate with foundry sand in which compressive and tensile strength were increased up to 20% whereas not much change occurred in modulus of elasticity. Also workability decreased with the increase of foundry sand content because of very fine particles.

Saraswati et al. The study focused on reviewed that compressive strength kept on increasing with an increase on waste foundry sand and the maximum compressive strength had achieved at 60% replacement of fine aggregates. They also reviewed that split tensile strength decreased with increase in percentage of waste foundry.

Athanasopoulou A. Kollaros G. et al studied the environmental benefits by Slag Use in Transportation Projects. The major objective of this research was to determine if it physically makes sense to use slag in pavement layers and to understand the environmental implications which include the reduction of virgin materials use, thus yielding cost and energy savings. Slags being used in roadway and pavement construction projects are by-products of the process of steel-making and electric power production where coal is burnt. Slag types vary according to their chemical composition, specific weight, and porosity. This lack of uniformity does not exist only between slags from different sources, but even in the same furnace and among its different loadings. Hardness and durability tests have been performed on various Greek slags, in order to define the engineering properties and characterize the material for use in pavement construction. The results have been compared with outputs for conventional hard aggregates. Synthetic aggregates can be used improving the costs of road products, while yielding significant energy savings and having mild impacts on the environment. A crucial factor for the successful use of a particular slag is the type of the material, which basically depends on the procedures followed in the metallurgy industry. So, criteria are needed for the mechanical behaviour of waste materials, especially slag, in road pavement construction. For a complete design procedure, a proper quantification of samples it is also needed.

Havanagi et al have investigated the suitability of waste materials (copper, zinc, and steel slags, as well as pond ash) as a replacement of fine aggregate in base and bituminous layers of road pavement, in terms of their physical, chemical and geotechnical properties. An effort has been made to ensure the stability of steel slag and to judge its feasibility as an aggregate to prepare stone mastic asphalt (SMA) mixtures, due to its porous structure. A comparison to mixtures with basalt aggregate employing X-ray diffraction (XRD), scanning electron microscopy (SEM), as well as mercury intrusion porosimetry (MIP) has shown a higher resistance of steel slag to permanent deformation at high temperature.

The environmental benefits from the use of slag aggregates in road construction are:

- A high level of skid resistance is maintained throughout the pavement’s life due to the regeneration of the aggregates surface texture with use.
- Steel slag aggregate eliminates the need for quarrying while in the same time avoids landfill of steelmaking slag; thus sustainability is obviously added to the environment.
- Energy and natural resources savings are achieved through the recycling processes of steel by-products production
- Acidic conditions are neutralized by slag making it advantageous against natural aggregates
- The natural landscape remains untouched, since all excavations are avoided.
- The need to transport aggregates from quarries located in long distances from the construction site, creates carbon emissions along with its high cost. These emissions are reduced when locally available slag is used and of course by the longer life of the pavement requiring less maintenance and replacement in the long-term.

Sivapriya S.V stated the utilization of copper slag as a reinforcing material. The central pollution control board (CPCB) has recommended usage of copper slag in cement manufacturing process as well as in landfill application. The reuse of waste material is an “STATE – OF – ART”. In view to it, CS is used as a replacement material in stabilizing the soil. To study the influence of CS in shear strength property of soil, laboratory tests were conducted. The physical and geotechnical properties were compared with those of conventional fill materials such as sands. Different percentage of CS is added (0, 10, 20 and 30%) by weight to the soil and their corresponding unit weight and angle of internal friction was found. The obtained values are taken as input parameters to find the stability of slope using Finite Element Analysis. There is linear increase in maximum dry unit weight and angle of internal friction of the soil with increase in replacement of CS till 30%. At 30% replacement of CS with the sand shows significant increase in factor of safety of an unstable slope.

CONCLUSION

The objective of road constructions and others structure is to contain the waste material in a manner that is protective to human health and the environment. On the basis of above study, following conclusions is drawn:

1. Marshall Stability value for 24% copper slag addition is greater than 12%, 36% and 48% copper slag addition and almost double then conventional samples.
2. The optimum bitumen content is 4.28 % after studying the Marshall Stability test.
3. The optimum slag content is 24 % after studying the Marshall Stability test.
4. Air voids remain almost same as compared to HMA at 24% copper slag.
5. The physical properties of copper slag bituminous mixture basically satisfy the requirements of Marshall Specification for the design.
6. The use of copper slag for road construction can save the environment, increase the service life of roads and serve the society with additional income for those associated with it.
7. The voids filled with bitumen increases with increase in the bitumen Content.

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