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Usage of Industrial Waste Products in Village Road Construction

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Abstract—**Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. In recent years, applications of industrial wastes have been considered in road construction with great interest in many industrialised and developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. India has a large network of industries located in different parts of the country and many more are planned for the near future. Several million metric tons industrial wastes are produced in these establishments. If these materials can be suitably utilised in highway construction, the pollution and disposal problems may be partly reduced. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. A review of various Industrial wastes for use in the construction of highway has been discussed in this paper. The waste materials are fly ash, blast furnace slag, cement kiln dust phosphogypsum, waste plastic bags, foundry sand and colliery sand , which are the industrial wastes posing problems in the disposal and being deposited near the industries in India.**

Index Terms— **Industrial Wastes, Fly Ash, Blast furnace slag, Cement kiln dust, Phosphogypsum, Waste plastic bags, Foundry sand and colliery sand**

I. Introduction

Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. In recent years, applications of industrial wastes have been considered in road construction with great interest in many industrialised and developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. The lack of traditional road materials and the protection of the environment make it imperative to investigate the possible use of these materials carefully. India has a large network of industries located in different parts of the country and many more are planned for the near future. Several million metric tons industrial wastes are produced in these establishments.

Traditionally soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and industrial wastes product is one such category. If these materials can be suitably utilised in highway construction, the pollution and disposal problems may be partly reduced. In the absence of other outlets, these solid wastes have occupied several acres of land around plants throughout the country. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximise the use of solid wastes in different layers of the road pavement.

Post construction pavement performance studies are to be done for these waste materials for construction of low-volume roads with two-fold benefits: (a) it will help clear valuable land of huge dumps of wastes; (b) it will also help to preserve the natural reserves of aggregates, thus protecting the environment.

In the absence of other outlets, these solid wastes have occupied several acres of land around plants throughout the country. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximise the use of solid wastes in different layers of the road pavement. Post construction pavement performance studies are to be done for these waste materials for construction of low-volume roads with two-fold benefits: (a) it will help clear valuable land of huge dumps of wastes; (b) it will also help to preserve the natural reserves of aggregates, thus protecting the environment. Materials such as fly-ash from thermal power plants and other coal fired industries, blast furnace slag from steel industries, cement kiln dust from cement related industries, phosphogypsum from phosphatatic fertilizer industries, and many other solid wastes have already proved to be useful for road construction in many countries.

II. Fly Ash

Fly ash is the finely divided residue that results from the

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combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric bag houses. Fly ash is most commonly used as a pozzolana in Portland cement concrete applications. Pozzolanas are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. The unique spherical shape and particle size distribution of fly ash make it good mineral filler in hot mix asphalt (HMA) applications and improves the fluidity of flowable fill and grout. The consistency and abundance of fly ash in many areas present unique opportunities for use in structural fills and other highway applications. There are three types of fly ashes, namely, fly ash, bottom ash and pond ash. Fly ash and bottom ash when transported and disposed to the pond it is termed as pond ash.

A. Use of fly ash in Portland cement concrete for applications in highway construction

Fly ash is used in concrete admixtures to enhance the performance of concrete roads and bridges. Portland cement contains about 65 percent lime. Some of this lime becomes free and available during the hydration process. When fly ash is present with free lime, it reacts chemically to form additional cementitious materials, improving many of the properties of the concrete.

There are many advantages of incorporating fly ash into a Portland cement concrete which have been demonstrated through extensive research and countless highway and bridge construction projects. Benefits to concrete vary depending on the type of fly ash, proportion used, other mix ingredients, mixing procedure, field conditions and placement. Some of the advantages of fly ash in concrete are mentioned below:

- Higher ultimate strength;
- Improved workability;
- Reduced bleeding;
- Reduced heat of hydration;
- Reduced permeability;
- Increased resistance to sulphate attack;
- Increased resistance to alkali-silica reactivity (ASR);
- Lowered costs;
- Reduced shrinkage; and
- Increased durability.

B. Use of fly ash in stabilised base course for applications in highway construction

Fly ash and lime can be combined with aggregate to produce a quality stabilized base course. These road bases are referred to as pozzolanic-stabilized mixtures (PSMs). Typical fly ash contents may vary from 12 to 14 percent with corresponding lime contents of 3 to 5 percent. Portland cement may also be used in lieu of lime to increase early age strengths. The resulting material is produced, placed, and looks like cement stabilized aggregate base. Pozzolanic-stabilized mixture bases have advantages over other base materials which are shown below:

- Use of locally available materials;
- Provides a strong, durable mixture;
- Increased energy efficiency;
- Suitable for using recycled base materials; and
- Can be placed with conventional equipment.

C. Use of fly ash in soil improvement for applications in highway construction

Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. The properties of soil which can be change by using of fly ash are density, water content, plasticity, strength and compressibility performance of soils, hydraulic conductivity, and so on. Typical applications include: soil stabilization, soil drying, and control of shrink-swell. Fly ash provides the following advantages when used to improve soil conditions:

- Eliminates need for expensive borrow materials;
- Expedites construction by improving excessively wet or unstable sub grade;
- By improving sub grade conditions, promotes cost savings through reduction in the required pavement thickness; and
- Can reduce or eliminate the need for more expensive natural aggregates in the pavement cross-section.

D. Use of fly ash in asphalt pavements for applications in highway construction

Fly ash can be used as mineral filler in hot mixed asphalt (HMA) paving applications. Mineral fillers increase the stiffness of the asphalt mortar matrix, improving the resistance of pavements, and the durability of the mix. Fly ash will typically meet mineral filler specifications for gradation, organic impurities, and plasticity. The advantages of fly ash which are mentioned in the following:

- Reduced potential for asphalt stripping due to hydrophobic properties of fly ash;
- Lime in some fly ashes may also reduce stripping; and
- May afford a lower cost than other mineral fillers.

E. Use of fly ash in grouts for pavement subsealing for applications in highway construction

Grouts are proportioned mixtures of fly ash, water, and other materials used to fill voids under a pavement system without raising the slabs or to raise and support concrete pavements at specified grade tolerances by drilling and injecting the grout under specified areas of the pavement. Following are the advantages of fly ash grouts:

- Be used to correct undermining without removing overlying pavement;
- Be accomplished quickly with minimum disturbance to traffic; and

- Develop high ultimate strength.

III. Blast Furnace Slag

Blast furnace slag is generated during the melting process in steel making operations. The slag is a fairly complex mass that is relatively inert. It is composed of metal oxides (produced as a result of the oxidation of the metal during the melting process), melted refractory, sand from recycled scrap castings, coke ash, and other materials. The physical form of the slag largely depends on the method of collection. Slag that is quenched in water will typically form gravel sized particles. Slag that is removed from the furnace and poured into sand moulds or "pigs" will typically resemble boulder sized masses. This type of slag is generally in the shape of a flat piece of metal and/or small rock sized chunks.

Blast furnace slag has been beneficially used in a number of applications. The most significant factor that determines whether or not blast furnace slag is suitable for use is the particle size. Most of the blast furnace slag that has been used has either been generated as part of a wet quenching collection system, or if collected dry, has undergone some particle size reduction. Some of the potential beneficial uses for blast furnace slag are as follows:

A. Use of blast furnace slag as a cementitious binder for applications in highway construction

Blast furnace slag has been used as a cementitious binder in road construction. The properties of blast-furnace slag have been developed in France under the title gravel-slag to stabilise gravel and sands for sub-base and base construction. Gravel-slag is the most widely used road base material in France and it is estimated that 65 percent of French roads have a pavement layer composed of gravel-slag. Following are the advantages of blast furnace slag as a cementitious binder:

- There is a development of better strength;
- It can be used in labour intensive construction, the slag would be mixed in a locally based central mixing plant, and then hauled, spread, shaped, compacted and cured using labour intensive methods;
- Low energy requirement – only grinding of material is needed;
- Significant lower capital requirements as compared to cement;
- Mixing lime and granulated blast furnace slag with 7.5 percent gypsum can be used for making mortars;
- It can be used for making concrete mixes for use in road bases and composite pavements;
- This provides a great potential for profitable use of this waste material and produces alternate binder to cement; and
- Within 30 km area of steel plants it is economical than conventional materials.

B. Use of blast furnace slag as a coarse aggregate for asphalt for applications in highway construction

Just as foundry slag has been used as a substitute for native coarse aggregate in concrete mixtures, it has also been used in asphalt mixtures. Here again, the slag is usually crushed to achieve the desired particle size. In general, the slag is crushed so that it will pass the ¾ inch sieve. In addition to the larger aggregate, the desired mix will also contain about 7 to 8 percent fines that pass the 200 sieve. The advantages of blast furnace slag as a coarse aggregate for asphalt which are mentioned in the following:

- Lower cost than other mineral fillers; and
- Suitable for roads near the locality of the steel plants.

C. Use of blast furnace slag as a coarse aggregate for sub-base for applications in highway construction

Many steel plants have used their slag as a substitute for coarse aggregate in road construction projects in and around the steel plants for a number of years. In many cases, it has been used as the single source of material for gravel road construction. In other instances, it is used for roadbed, base course, or sub base material. Blast furnace slag provides the following advantages when used as a coarse aggregate for sub-base:

- Slag that has been water quenched tends to have a lowered wear resistance and soundness;
- For most sub base applications in which above two properties are critical, aircooled, as opposed to waterquenched, slag is used. Most often, aircooled slag is crushed to a ¾inch particle size or less in order to meet most state coarse aggregate specifications. Once properly sized, these byproducts can serve as suitable substitutes for native coarse aggregate in this application; and
- The sections of roadway in which blast furnace slag was used as a means of providing soft ground stabilization provided a degree of stabilization equivalent to that of the traditional method of using rock aggregate.

IV. Cement Kiln Dust

Cement kiln dust (CKD) is the finely divided dry alkaline particulate matter carried from a cement kiln by the exhaust gas, and captured by the kiln's air pollution control system. In general, however, the composition of cement kiln dust is similar to that of cement and consists of calcium carbonate, calcite, silicate, potassium sulphate, calcium sulphate, aluminium oxide, iron oxide, potassium chloride, magnesium oxide, sodium sulphate, and potassium fluoride. Cement kiln dust has a chemical composition similar to that of cement; therefore, the primary value of cement kiln dust is its cementitious properties. Its alkalinity and particle size also provide value for a variety of beneficial use options.

A. Use of cement kiln dust for soil stabilisation for applications in highway construction

Cement kiln dust can be used to improve the properties of soil in situ, and as an activator in pozzolanic stabilised base mixtures. The adsorptive capacity and cementitious properties of cement kiln dust allow it to reduce the moisture content and increase the bearing capacity of the soft soil. Cement kiln dust for soil stabilisation have advantages which are shown below:

- Cement kiln dust effectively improves soil strength and also reduces construction time and costs;

- When lime is used as a stabilizing agent, the soil must be remixed and compacted 48 hours after the lime is first applied;
- When cement kiln dust is used as a stabilising agent, the mixing and compacting of cement kiln dust are completed when it is initially applied or within 24 hours; and
- Cement kiln dust can be mixed with soil to modify plastic limits or moisture content to provide the desired stabilised properties.

B. Use of cement kiln dust as mineral filler in asphalt paving for applications in highway construction

Hot-mixed asphalt (HMA) is a common paving material. Hot-mixed asphalt is made by coating of dried coarse and fine aggregates with hot asphalt cement, which acts as a binder. Cement kiln dust can be used to replace a portion of the mineral filler used in hot-mixed asphalt. Cement kiln dust as mineral filler in asphalt paving have following advantages:

- Current specifications for mineral filler in hot-mixed asphalt (AASHTO M17) are for material passing the No. 50 sieve to be between 95 and 100 percent. Typically, the maximum particle size of cement kiln dust is about 0.3 mm (No. 50 Sieve), which conforms to the mineral filler topsize requirements; and
- Its desirable physical properties, the cementitious properties of cement kiln dust have been shown to increase the stability and stiffening of hot-mixed asphalt.

V. Phosphogypsum

In fertilizer industries the Phosphate rock, is processed to make phosphoric acid, contains about 70 percent calcium phosphate, also contain a large number of impurities, such as calcium fluoride, chlorides, chromium, and many other compounds. In the wet process the phosphate rock is treated with sulfuric acid to produce the phosphoric acid which is the finished product in the fertilizer. The by-product remaining after the acid conversion is largely calcium sulfate and has been given the name phosphogypsum. Phosphate production generates huge amounts of wastes. The production of each ton of phosphoric acid is accompanied by the production of 4½ tons of phosphogypsum. The phosphogypsum is stored in open-air storage areas known as stacks. The stacks form as the slurry containing the by-product phosphogypsum is pumped onto a disposal site. Over time the solids in the slurry build up and a stack forms. The stacks are generally built on unused or mined out land on the processing site. The surface area covered by stacks ranges from about 5 to 740 acres. The height ranges from about 10 to 200 feet.

Phosphogypsum is reused for highway construction aggregate (crushed base and crushed aggregate for asphalt).

VI. Conclusions

A review of various Industrial wastes for use in the construction of highway has been discussed in this paper. The waste materials are fly ash, blast furnace slag, cement kiln dust and phosphogypsum which are the industrial wastes posing problems in the disposal and being deposited near the industries in the state of Orissa. The following are the conclusions made from the above study:

1) Fly ash can be used in concrete admixtures to enhance the performance of concrete roads and bridges.
2) Incorporating fly ash into a Portland cement concrete vary depending on the type of fly ash, proportion used, other mix ingredients, mixing procedure, field conditions and placement.
3) Fly ash and lime can be combined with aggregate to produce a quality stabilized base course. Portland cement may also be used in lieu of lime to increase early age strengths.
4) Fly ash is an effective agent for chemical and/or mechanical stabilization of soils.
5) By improving sub grade conditions by using fly ash, promotes cost savings through reduction in the required pavement thickness.
6) Fly ash can be used as mineral filler in hot mixed asphalt (HMA) paving applications.
7) Grouts are proportioned mixtures of fly ash, water, and other materials used to fill voids under a pavement system without raising the slabs or to raise and support concrete pavements.
8) Blast furnace slag has been used as a cementitious binder in road construction.
9) Blast furnace slag provides a great potential for profitable use of this waste material and produces alternate binder to cement.
10) Just as foundry slag has been used as a substitute for native coarse aggregate in concrete mixtures, blast furnace slag has also been used in asphalt mixtures.
11) Many steel plants have used their slag as a substitute for coarse aggregate in road construction projects in and around the steel plants for a number of years. In many cases, it has been used as the single source of material for gravel road construction. In other instances, it is used for roadbed, base course, or sub base material.
12) The sections of roadway in which blast furnace slag was used as a means of providing soft ground stabilization provided a degree of stabilization equivalent to that of the traditional method of using rock aggregate.
13) Cement kiln dust has a chemical composition similar to that of cement; therefore, the primary value of cement kiln dust is its cementitious properties. Its alkalinity and particle size also provide value for a variety of beneficial use options.
14) Cement kiln dust can be used to improve the properties of soil in situ, and as an activator in pozzolanic stabilised base mixtures. The adsorptive capacity and cementitious properties of cement kiln dust allow it to reduce the moisture content and increase the bearing capacity of the soft soil.
15) Cement kiln dust can be mixed with soil to modify plastic limits or moisture content to provide the desired stabilized properties.

16) Hot-mixed asphalt (HMA) is a common paving material. Cement kiln dust can be used to replace a portion of the mineral filler used in hot-mixed asphalt.
17) Phosphogypsum is reused for highway construction aggregate.

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