



A STUDY ON THE USE OF INDUSTRIAL WASTES OF RIGID PAVEMENTS TO REDUCE CARBON FOOTPRINT IN RURAL ROAD CONSTRUCTION

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ABSTRACT: In the current situation, safe disposal of industrial wastes is a major issue. Because many of these waste products are non-biodegradable, they cause contamination in the surrounding ecosystem. According to studies, industrial wastes have been effectively employed in road building in several industrialized nations in recent years. The usage of these materials in road construction is based on technical, economic, and environmental considerations. India has a large network of industries spread around the nation, with many more on the way in the near future. These industries generate millions of metric tons of industrial trash. By using these materials effectively in highway building, pollution and disposal issues may be reduced. It is critical to evaluate these materials and create a technique and criteria to improve the usage of these industrial wastes in road building in India. These materials should be developed for the building of low-volume highways in various locations of our nation. This study discusses a review of different industrial wastes to be utilized in highway building. Fly ash, blast furnace slag, cement kiln dust, phosphor gypsum, waste plastic bags, foundry sand, and colliery sand are examples of common waste products.

KEYWORDS: Industrial wastes, Fly Ash, Blast furnace slag, Cement kiln dust, Phosphor gypsum, Waste plastic bags, Foundry sand and colliery sand.

1.INTRODUCTION

Rural roads are often low-cost roads, thus the requirements for the pavement materials used in the different layers should be as affordable as possible while still taking into account the projected volume of traffic and the local climate. To the greatest degree practical, local materials that are less expensive and need less freight should be utilised. Safely disposing of the many industrial wastes that are created nowadays is a major issue. Since many of these materials are non-biodegradable, they pollute the ecosystem around. Industrial wastes have recently been used in underdeveloped nations to build roads. These materials are used in road construction depending on technical, financial, and environmental considerations. It is crucial to properly research the potential usage of these materials due to the shortage of conventional road materials and environmental protection concerns. India has a vast network of industries spread around the nation, and many more are anticipated in the near future. In these facilities, industrial wastes amount to several million metric tonnes. For the building of roads, traditional materials include soil, stone aggregates, sand, bitumen, cement, etc. Natural resources are exhaustible; hence their availability is decreasing with time. Additionally, the

cost of obtaining high-quality natural resources is rising. Scientists are searching for substitute resources for building highways as a result of this concern, and one such category is industrial waste products. The pollution and disposal issues could be partially resolved if these materials can be used effectively in highway building. These solid wastes have taken up many acres of ground near factories around the nation since there are no other places for them to go. It was deemed practical to test these materials and set standards to improve their usage of these industrial wastes in road construction, where a better rate of returns may be conceivable, keeping in mind the necessity for mass use of these solid wastes in India. The potential use of these materials should be explored for the development of rural low-volume highways in various regions of our nation. In order to optimize the usage of solid wastes in the various layers of the road pavement, the relevant requirements should be developed. After completion for the purpose of building low volume roads, pavement performance studies for these waste materials are to be conducted.

2.ADVANTAGES

(a). it will free up valuable land from massive waste dumps.

(b). it will help preserve the natural aggregate reserves, protecting the environment. Road construction has already proven to be a successful use of 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, phosphonyls from phosphatidic fertilizer industries, and many other solid wastes in many different nations.

3. METHODOLOGY & USES & PROPERTIES OF INDUSTRIAL WASTE MATERIALS

A- Fly ash: Fly ash is a finely separated by product of pulverized coal combustion that is carried away from the combustion chamber by exhaust gases. Coal-fired power and steam generating facilities release fly ash into the environment. Typically, coal is ground and air is forced into the combustion chamber of the boiler where it ignites instantly, creating heat and a molten mineral residue. The flue gas is cooled by the heat extracted from the boiler via the boiler tubes, which also causes the molten mineral waste to solidify into ash. The lighter, finer ash particles, known as fly ash, stay suspended in the flue gas while the heavier, coarser ash particles, known as bottom ash or slag, sink to the bottom of the combustion

chamber. Fly ash is eliminated by particle emission control mechanisms such as electrostatic precipitators or filter fabric bag houses before the flue gas is exhausted. The most typical use for fly ash is as a pozzolana in Portland cement concrete. Pozzolanas are siliceous or siliceous and aluminous minerals that, when combined with calcium hydroxide at room temperature and in the presence of water, make cementitious compounds. Fly ash is a useful mineral filler in hot mix asphalt (HMA) applications because of its distinctive spherical form and particle size distribution, which also increases the fluidity of flowable fill and grout. Fly ash has special prospects for usage in structural fills and other roadway applications due to its uniformity and quantity in many regions. Fly ashes come in three different varieties: pond ash, bottom ash, and fly ash. When carried and dumped in a pond, fly ash and bottom ash are referred to as pond ash.

- Favourable properties of fly ash
- Light weight, lesser pressure on sub-soil
- High shear strength
- Coarser ashes have high CBR value
- Pozzolanic nature, additional strength due to self-hardening
- Amenable to stabilization
- Ease of compaction

- High permeability
- Non plastic
- Faster rate of consolidation and low compressibility
- Can be compacted using vibratory or static roller

Table 1: Engineering properties of Fly ash

Parameter	Range
Specific Gravity	1.90–2.55
Plasticity	Nonplastic
Maximum dry density (gm/cc)	0.9–1.6
Optimum moisture content (%)	38.0– 18.0
Cohesion (KN/m ²)	Negligible
Angle of internal friction (ϕ)	30 ⁰ –40 ⁰
Coefficient of consolidation C _v (cm ² /sec)	1.75x10 ⁻⁵ –2.01x10 ⁻³
Compression index C _c	0.05– 0.4
Permeability (cm/sec)	8x10 ⁻⁶ –7x10 ⁻⁴
Particle size distribution (% of materials)	
Clay size fraction	1 – 10
Silt size fraction	8 – 85
Sand size fraction	7 – 90
Gravel size fraction	0 – 10
Coefficient of uniformity	3.1 – 10.7

• **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
- Increased durability

• **Use of fly ash in stabilized 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 (PSM). 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
- Can be placed with conventional equipment

•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 (as the CBR value increases)
- Can reduce or eliminate the need for more expensive natural aggregates in the pavement cross-section

• 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 to increase its density. 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
- May afford a lower cost than other mineral fillers.

• **Use of fly ash in grouts for pavement sub sealing 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
- Develop high ultimate strength.

B- 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:

Slags: Total production of slag from steel industries is about 8.0 million tonnes. Types of slags- Blast furnace slag

- Granulated blast furnace slag (GBFS)
- Air cooled slag
- Steel slag
- Granulated blast furnace slag
- Contains reactive silica
- Suitable for lime / cement
- Air cooled blast furnace slag
- Non – reactive
- Suitable for use as coarse aggregates
- Steel slags
- Obtained as a waste product during production of steel.
- Particle size varies from 80 mm to 300 microns.

- Compared to blast furnace slag, steel slag contains lower amount of silica, higher amounts of iron oxide and calcium oxide.

- Due to presence of free lime, steel slag should be weathered before using it in construction.

Table 2: Properties of air-cooled slag of Indian plant

Property	Durgapur	Bhilai	Rourkela	Delhi Quartzite	Specification requirements
Specific gravity	2.78–2.82	2.82–3.33	2.97–2.99	2.67	-
Water absorption(%)	1.53–1.72	0.58–1.38	0.74–1.29	0.48	2%Max
Los Angeles abrasion value(%)	18.80	25.00	14.28	34.00	40%Max
Impact value(%)	15.79	14.80	16.90	24.50	30%Max
Soundness value(%)	1.66	1.17	0.33	0.17	12%Max
Percentage voids	46.40	43.90	43.10	43.80	-

- 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 stabilize 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.
- 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 sieves. The advantages of blast furnace slag as coarse aggregate for asphalt which are mentioned in the following:

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

•Use of blast furnace slag as a coarse aggregate for subbase 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, air cooled, as opposed to water quenched, slag is used. Most often, air cooled slag is crushed to a ¾inch particle size or less in order to meet most state coarse aggregate specifications. Once properly sized, these by products can serve as suitable substitutes for native coarse aggregate in this application.

•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.

C- 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.

Table 3: Typical Composition of Cement kiln dust (CKD)

Constituents	Weight in (%)	Constituents	Weight in (%)
CaCO ₃	55.5	Fe ₂ O ₃	2.1
SiO ₂	13.6	KCl	1.4
CaO	8.1	MgO	1.3
K ₂ SO ₄	5.9	Na ₂ SO ₄	1.3
CaSO ₄	5.2	KF	0.4
Al ₂ O ₃	4.5	Others	0.7

•Use of cement kiln dust for soil stabilization 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 stabilized 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 stabilization have advantages which are shown below:

•Cement kiln dust effectively improves soil strength and also reduces construction time and cost.

•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 stabilizing agent, the mixing and compacting of cement kiln dust are completed when it is initially applied or within 24 hours.

•Cement kiln dust can be mixed with soil to modify plastic limits or moisture content to provide the desired stabilized properties.

•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 top size requirements.

•Its desirable physical properties, the cementitious properties of cement kiln dust have been shown to increase the stability and stiffening of hot-mixed asphalt.

D-Phosphor gypsum: 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 sulphuric 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 sulphate and has been given the name phosphor gypsum. Phosphate production generates huge amounts of wastes. The production of each ton of phosphoric acid is accompanied by the production of 4½ tons of phosphor gypsum. The phosphor gypsum is stored in open-air storage areas known as stacks. The stacks form as the slurry containing the by-product phosphor gypsum 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. Phosphor gypsum is reused for highway construction aggregate (crushed base and crushed aggregate for asphalt).

•**Characteristics of phosphor gypsum:** Phosphor gypsum is a gray coloured, damp, fine grained powder, silt or silty-sand material with a maximum size range between 0.5 mm (No. 40 sieve) and 1.0 mm (No. 20 sieve) and the majority of the particles (50-75 %) are finer than 0.075 mm (No. 200 sieve). The specific gravity of phosphor gypsum ranges from 2.3 to 2.6. The maximum dry bulk density is likely to range from 1470 to 1670 kg/m³, based on Standard Proctor Compaction. The gypsum cake, after filtration, usually has free moisture content between 25 and 30%. Hemihydrate, in the presence of free water will rapidly convert to dihydrate and in the process, if left undisturbed will set into a relatively hard cemented mass and does not cause dust problem unless disturbed. Phosphor gypsum consists of primarily of calcium sulphate dihydrate with small amounts of silica, usually as quartz and unreacted phosphate rock, radioactive material (like radium, uranium), heavy metals namely arsenic, cadmium, chromium, mercury and fluoride. The concentration of the metals

depends on the composition of the phosphate rock. The following are the main concerns with respect to management of phosphor gypsum; i) High fluoride concentration (in the range of 0.5 -1.5 %) may leach fluoride and contaminate the groundwater, if not stored and handled properly; ii) Presence of radio-nuclide radium -226 which upon decay may emits harmful alpha particles; iii) May contain heavy metals (Cd, Cr, Pb etc) that may enter into the food chain through potable water and agriculture products. Permeability of phosphor gypsum depends on stabilization. Permeability in unsterilized phosphor gypsum has been found to range from 1.3×10^{-4} cm/sec down to 2.1×10^{-5} cm/sec for stabilized phosphor gypsum. Typical chemical characteristics of the phosphor gypsum is given in Table 4, as shown below-

Table 4: Typical chemical composition of the phosphor gypsum

Parameter	Compositionin %
H2O _{cyst}	18.0
SO ₂	43.6
CaO	32.0
MgO	0.40
Al ₂ O ₃ +Fe ₂ O ₃	1.82
SiO ₂ insinHcl	1.64
Na ₂ O	0.36
P ₂ O ₅ total	1.03
F _{total}	0.76
Organicmatter	0.26

E- Waste plastic bags: In India 330 million People depending on Plastic bags. India ranks III in the world in the consumption of plastics. It is found that shredded plastic waste of the size 2-8 mm may be incorporated conveniently in bituminous mixes used for road constructions. The optimum dose is around 0.4- 0.5 % by weight of bituminous mix and 6-8% by weight of bitumen. Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted. The role of waste plastic bags in the mix was studied for various engineering properties by preparing Marshall samples of BC mixtures with and without polymer. Marshall properties such as stability, flow value, unit weight, air voids were used to determine optimum polythene content for the given grade of bitumen (80/100). Thin plastic bags are mainly composed of low-density Polyethylene (LDPE) and it's commonly used for packaging, protecting and many other applications. In this research, Waste Plastic Bags (WPB) as one form of polymers were used to investigate the potential prospects to enhance asphalt mixture properties. Study aims include studying the effect of adding

different percentages of grinded WPB as an aggregate coat on the properties of asphalt mix comparing it with conventional mix properties besides identifying the optimum percent of WPB to be added in the hot mix asphalt. Results indicated that WPB can be conveniently used as a modifier for asphalt mixes as a part of sustainable management of plastic waste as well as for improved performance of asphalt mix. WPB content around 10% by weight of Optimum Bitumen Content was recommended as the optimum WPB content for the improvement of performance of asphalt mix. Thermal gravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C. Moreover, the softened plastics have a binding property. Hence, the molten plastics materials can be used as a binder and/or they can be mixed with binder like bitumen to enhance their binding property. This may be a good modifier for the bitumen, used for road construction.

Table 5: Thermal Behaviour of Polymers

Polymer	Solubility		Softening Temp. in °C	Product reported
	Water	EPT*		
PE	Nil	Nil	100-120	No Gas
PP	Nil	Nil	140-160	No Gas
PS	Nil	Nil	110-140	No Gas

De composition Temp.in °C	Product reported	Ignition Temp. Range in °C	Product reported
270-350	CH ₄ , C ₂ H ₆	>700	CO, CO ₂
270-300	C ₂ H ₆	>700	CO, CO ₂
300-350	C ₆ H ₆	>700	CO, CO ₂

Note: - EPT = Extraction Process of Toxify
Waste plastics properties are shown in table6 given below:

Table 6: Waste plastics properties

Property	Details
Plastic type	Grinded wastethin plastic packaging bags
Plastic material	Low density Polyethylene (LDPE)
Size(mm)	Passing 2.36 mm Sieve and retained on 600µ sieve
Density(g/cm ³)	0.92
Melting point(°C)	120-130

F- Foundry and colliery sand: The foundry industry utilizes industrial grade silica sand for moulds in metal casting. Waste foundry sand is a by-product of the foundry casting process of ferrous and nonferrous metals, 95% of this material is generated from the ferrous casting process. Spent foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. Ferrous industries account for the majority of foundry sand used. Foundry sand may also contain some leachable contaminants, with non-ferrous foundry sands frequently containing high levels of heavy metals classified as hazardous. Colliery spoil is the waste material produced from the process of extracting coal and rendering it marketable. When the coal is processed by washing prior to sale to the customer, colliery spoil is produced in the form of coarse or fine discard. It can be used in fill although a major use is in infrastructure applications. Most colliery spoil is used as bulk fill, notably for construction lagoons, river banks and for capping landfill or general ground raising. It is also used for flood protection works, beach replenishment and road construction. There is burnt and unburnt colliery spoil, which have very different properties. Burnt spoil is generally of higher strength than

unburnt spoil and is consequently in higher demand.

G- Processed Municipal solid waste: Management of Municipal Solid Wastes (MSW) continues to remain one of the most neglected major issues in Indian cities due to the rapid urbanization, urban population growth and industrialization. Most of local administrations are directly dumping MSW without any segregation and treatment to the open dumping site, this manner of inappropriate disposal of MSW is become a major threat to the environments and public health in developing countries like India. The quantity of municipal solid wastes generated in India has been consistently rising over the years. This can be attributed to the rapid population growth, mass migration of population from rural to urban areas, Rapid industrialization and increase in economic activities in general and the change in lifestyle of the people. As per report (May 2000) of Ministry of Urban Development (MoUD), Government of India that 1,00,000 MT of Municipal Solid Waste was generated daily in the country. The survey conducted by the central institute of Plastics Engineering and technology (CIPET) at the instance of CPCB has reported generation of 50,592 tons of MSW per day in the year 2010-11 in some 59 cities. The

MSW quantity is expected to increase significantly by the year 2020 due to the growth in population, living standards of the residents and degree of commercialization, industrialization and various other activities. It can be utilized in various construction and other activities given below to avoid the pollution and give a way for safe disposal as well. They are-

- Embankment fill
- Road base material
- Aggregate for asphalt
- Aggregate for concrete building blocks
- Cement bound material
- Lime/fly ash mixtures
- Landfill drainage media.

4.RESULT & DISCUSSION

1. Construction Methods and Technology: Road construction techniques have been constantly upgraded and use of new and alternative materials as well as modern equipment's is advocated for all types of roads. It is logical to see that the purpose of road construction is to provide a firm, durable and even surface of pavement, which could stand the stresses imparted due to traffic and climatic conditions. The construction techniques for rural roads could be broadly classified as:

- (i) Conventional,
- (ii) Mechanized
- (iii) Intermediate.

Since rural roads are to be considered as engineering assets, they are required to be properly designed and constructed with high quality. This can be achieved only if proper use of high-end equipment for bulk construction of road works.

2. Conventional Methods and Technology:

The current practice of construction and maintenance of rural roads continue to be traditional. Though there is an increasing awareness regarding the need of maximizing use of locally available materials, adoption of soil stabilisation techniques and relevance of sealed gravel roads for low volume traffic conditions, cost effectiveness practices have not yet found favour in most of the rural road construction. Deployment of equipment/plant by and enlarge is the same as is being used for higher category of roads. State may have a mechanism of interacting with financial institutions, contractors and equipment manufacturers to facilitate the availability of required machinery for construction and maintenance of rural roads.

3. Labour-based Technology: As the rural population grows in the coming years, off-

farm employment opportunities need to be created to contain migration of rural population to towns and cities. Road construction and maintenance using labour-based technology promises to be a good avenue for creating employment potential while building productive assets. Many of the operations involved in rural road construction on such as excavation, embankment construction, soil-stabilisation, surface dressing, maintenance operations like trimming of berms and cutting grass and weeds, are easily amenable to be undertaken by manual means with support of light equipment. Provision of better tools to enhance the productivity of labour and training of the work-force will help in the process. International experience from China and several African countries suggests that most of the operations involved in the construction and maintenance of Rural Roads can be efficiently performed by labour, aided by simple implements to increase their productivity.

4. Intermediate Construction Technology and Equipment: The construction of rural roads in our country is largely with conventional techniques and is labour intensive. However, these techniques are slow and often result in sub-standard quality of finished product. On the other

hand, machine-based technologies are capital intensive and hence cannot be pressed for low volume rural road construction. Keeping in view the importance of employment opportunities and at the same time ensuring a minimum standard quality necessitates adoption of intermediate technology. A study on use of tractor-powered technology using locally available agricultural machinery, tractors-tiller was developed. The important operations such as loosening the soil for excavation, site clearance, loading and unloading, pulverization, mixing of additives, watering, spreading of soil, additives, levelling of soil at desired camber and compaction can be done with such a machinery. Normally, these equipment's remain idle in the agricultural fields for a considerable time in rural areas during sowing-harvesting cycles and therefore facilitate their use with no further investment and simultaneously getting better productivity of existing machinery.

The equipment manufacturing industries needs to focus on intermediate and low-end technology machines which can be used cost effectively by the local contractors in construction and maintenance of rural roads. Simple equipment's such as Pedestrian Road rollers, chip sealing machines, simple equipment for spraying emulsion, cold mix plants of small capacity, pot hole kit are

some of the promising items of the equipment. There is a scope for developing a healthy equipment leasing industry in the private sector to reduce financial burden on contractors in the use of machinery.

5. Design Modifications: Indian Roads Congress has revised its design guidelines of flexible and rigid pavements for rural roads. However, performance-based design to be developed to further modify the design to provide improved performance. Such design shall be suiting to the need of terrain, climate, material availability, drainage condition, etc. and even at lower cost. This is to be an important target and also to use the non-conventional materials as primary material for rural roads with modified design.

6. Effect of Cost due to material haulage: In any road construction, substantial portion of the cost of construction is the materials cost. In many places in the country (like parts of UP and north Bihar, Mizoram, Tripura, etc) the materials like hard stone have to be hauled from a lead distance more than 100 to 200 km and sometimes up to 500 km. Use of locally available materials (with design modifications) and adopting appropriate construction technology may reduce the cost of construction drastically bringing down the cost of haulage from far away

distances. However, this requires considerable efforts right at the development of specifications for the marginal materials in the road construction, inclusion of the same in the standard specifications and insist that these be followed meticulously while preparing the project proposals. Appropriate R&D initiatives at the State will facilitate and accelerate the use of marginal materials for cutting down the cost of construction due to longer haulage of standard materials.

Table 6.1 provides an estimation of portion of labour, material and equipment which gives an idea of direct employment generation in road construction.

Table 6.1: Proportions of Labour, Materials and Equipment in Rural Road Construction

S.N.	Technology chosen	Proportion of			
		Materials	Labours	Equipment	Total
1	Purely labour oriented (Applicable to tracks and uncompacted roads)	60	40	-	100
2	Labour oriented, but with selective use of flight equipment (Intermediate technology)	60	25	15	100
3	Highly equipment oriented	60	5	35	100

(Source: Rural Road development Vision – 2025 Draft)

- Rural roads should be constructed by adopting the Intermediate Technology
- Low-cost marginal and industrial waste may be promoted for rural road construction; necessary design and specifications be developed.
- The standard construction technology should be used for ensuring quality of construction.
- Many lower cost technologies like soil stabilization are not used often due to lack of appropriate mechanical devices; such shortcomings must be removed by appropriate developments for machineries.

5. CONCLUSION

A review of various Industrial wastes for use in the construction of highway has been discussed above. The waste materials are fly ash, blast furnace slag, cement kiln dust phosphor gypsum, waste plastic bags, foundry sand, colliery sand and processed municipal solid waste (MSW) which are the industrial wastes posturing problems in the disposal and being deposited in the vicinity of industries in India. The following conclusions can be drawn from the study-

1. Fly ash can be used in concrete admixtures to enhance the performance of concrete roads and bridges. Incorporation of 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 moisture content. 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. Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. By improving subgrade conditions by using fly ash, promotes cost savings through reduction in the required pavement thickness due to increase in CBR value of subgrade. Fly ash can be used as mineral filler in hot mixed asphalt (HMA) to increase the density of bituminous mix in paving applications.

2.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.

3.Blast furnace slag has been used as a cementitious binder in road construction. Blast furnace slag provides a great potential for profitable use of this waste

material and produces alternate binder to cement.

4. 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.

5. 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.

6. 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.

7. 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. Cement kiln dust can be used to improve the properties of soil in situ, and as an activator in pozzolanic stabilized base mixtures.

8. 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.

9. Cement kiln dust can be mixed with soil to modify plastic limits or moisture content to provide the desired stabilized properties.

10. 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.

11. Phosphor gypsum is reused for highway construction aggregate.

12. Waste plastic bags in shredded form can be used in bituminous mixes of flexible pavements to improve its performance and to minimize consumption of bitumen around 10% of weight of optimum bitumen content (OBC).

13. Foundry, colliery sand and municipal solid waste can be utilized in road embankments and their bases.

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