A Study on Use of Industrial Wastes in Rural Road Construction to Achieve the goal of Atmanirbhar Bharat

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ABSTRACT: In present scenario safe disposal of Industrial wastes is a great problem. These waste materials create environmental pollution in the vicinity because many of them are non-biodegradable. Studies reveal that in recent years, industrial wastes were successfully used in road construction in many developed countries. The use of these materials in road making is based on technical, economic, and ecological criteria. India has a vast network of industries located in different parts of the country and many more are to come in the near future. Million metric tons industrial wastes are produced in these Industries. The pollution and disposal problems may be minimized by properly utilizing these materials in highway construction. It is important to test these materials and to develop a methodology and specifications to enhance the use of these industrial wastes for their effective utilization in road construction in India. The probable 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 to be used in the construction of highway has been discussed in this paper. The common waste materials are fly ash, blast furnace slag, cement kiln dust, phosphogypsum, waste plastic bags, foundry sand and colliery sand.

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

I. INTRODUCTION

Rural roads are essentially low cost roads, the specifications for pavement materials in various layers should be as economical as possible, consistent with the traffic expected to use the road and the climatic condition. In this angle, the local materials which are cheaper and involve minimum haulage should be used to maximum extent feasible. In present scenario safe disposal of different wastes produced from Industries is a great problem. These materials cause environmental pollution in the vicinity because many of them are non-biodegradable. In recent years, industrial wastes have been utilized in road construction in 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 utilized 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 convenient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher rate of returns may be possible. The possible use of these materials should be developed for construction of low- volume roads (Rural roads) in different parts of our country. The necessary specifications should be formulated and attempts are to be made to maximize 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. INDUSTRIAL WASTES AND THEIR USES

A- Fly ash: Fly ash is the finely divided residue that results from the 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.

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	Non plastic
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 (¢)	30^0 – 40^0
Coefficient of consolidation C_v (cm^2/sec)	1.75 x 10^{-5} – 2.01 x 10^{-3}
Compression index C_c	0.05 – 0.4
Permeability (cm/sec)	8 x 10^{-6} – 7 x 10^{-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; and
- 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; and
- □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; and
- □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; and
- 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 tones. 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

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 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.

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; 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.

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, aluminum 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	% by weight	Constituents	% by weight
$CaCO_3$	55.5	Fe_2O_3	2.1
SiO_2	13.6	KCl	1.4
CaO	8.1	MgO	1.3
K_2SO_4	5.9	Na_2SO_4	1.3
$CaSO_4$	5.2	KF	0.4
Al_2O_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 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 stabilizing 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 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; 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.

D- 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 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 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).

Characteristics of phosphogypsum: Phosphogypsum is a gray coloured, damp, fine grained powder, silt or silty-sand material with a maximum size ranges 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 phosphogypsum ranges from 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. Phosphogypsum 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 phosphogypsum; 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 phosphogypsum depends on stabilization. Permeability in unsterilized phosphogypsum has been found to range from 1.3 $x10^{-4}$ cm/sec down to 2.1 $x10^{-5}$ cm/sec for stabilized phosphogypsum. Typical chemical characteristics of the phosphogypsum is given in Table - 4, as shown below-

Table -4 - Typical chemical composition of the phosphogypsum

Parameter	Composition in %
H_2O cyst	18.0
SO_2	43.6
CaO	32.0
MgO	0.40
Al_2O_3+ Fe_2O_3	1.82
SiO_2 ins in Hcl	1.64
Na_2O	0.36
P_2O_5 total	1.03
F total	0.76
Organic matter	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.

Thermo 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	Decomposition Temp. in °C	Product reported	Ignition Temp. range in °C	Product reported
	Water	EPT*						
PE	Nil	Nil	100-120	No Gas	270-350	CH4.C2H6	>700	CO, CO2
PP	Nil	Nil	140-160	No Gas	270-300	C2H6	>700	CO, CO2
PS	Nil	Nil	110-140	No Gas	300-350	C6H6	>700	CO, CO2

EPT = Extraction Process of Toxity

Waste plastics properties are shown in table-6 given below-

Table -6- Waste plastics properties

Property	Detail
Plastic type	Grinded waste thin plastic packaging bags
Plastic material	Low density Polyethylene (LDPE)
Size (mm)	Passing 2.36 mm Sieve and retained on 600µ sieve
Density (g/cm3)	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 tones 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.

III. STUDY RESULTS

Construction Methods and Technology: Road construction techniques have been constantly upgraded and use of new and alternative materials as well as modern equipments 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 and
(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.

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.

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.

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 equipments 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 equipments 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.

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.

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 has 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

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

(Source: Rural Road development Vision t – 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 is not used often due to lack of appropriate mechanical devices; such shortcomings must be removed by appropriate developments for machineries.

IV. 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 phosphogypsum, 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. 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.

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

9- 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.

10- Phosphogypsum is reused for highway construction aggregate.

11- 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).

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

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