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Strategies for economical construction of rural roads

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Abstract

Poor construction and maintenance of rural roads is key component of poverty in rural areas. Rural road network constitutes the highest road network percentage of total road network in India, hence required a great care and huge investment while construction and maintenance. Therefore, there is an urgent need to construct and maintain the rural roads in an optimal manner.This existing huge rural road network is highlighting the need to take some effective measures for controlling and maintaining the deterioration of the rural road network. However, there are various issues like choice of appropriate type of pavement, economical construction of pavements depending upon traffic and sub grade soil requirements, quality assurance during construction and timely and effective maintenance during operation period of road etc. should be taken under consideration. There is a need to develop some innovative strategies for reducing cost of construction of rural roads. These strategies will be useful for achieving the best values possible for the available resources in providing and operating smooth safe and economical pavements for rural roads in India.

However, there are various issues like choice of appropriate type of pavement, economical construction of pavements depending upon traffic and sub grade soil requirements, quality assurance during construction and timely and effective maintenance during operation period of roads etc. Various factors are there that affects the construction cost like subgrade characteristics, drainage characteristics, material characteristics etc. All these factors are dependent upon availability of fund. Non-availably of the required standardized material for construction is the mostly seen in many states. Therefore, transportation of standardized material causes high increment in construction cost. To achieve economy, use of locally available materials will be more emphasized and strategies will be suggested to utilize locally available material more efficiently for construction of pavements. Thus, it is expected that such a study will be very useful to reduce the cost of construction, and thus well leads to economy in providing huge rural road infrastructure in the country.

Keywords: Reducing cost of construction, Rural roads, Economical, Strategies

1. Introduction

Around 65% of the Indian population is living in rural areas. People in rural areas should have the same quality of life as is enjoyed by people living in sub urban and urban areas. At 3.3 million km of aggregate road length, India has the second largest road network in the world, next to USA. In spite of having the biggest railway network, the road transport has remained a preferred choice in our country, because of its flexibility, accessibility to remote areas and adaptability to changes for achieving the desired objective of connectivity. The overall development of any country depends on a good and well-connected road network. All other infrastructure developments, in turn, get benefited by such wide spread road network.

The overall development of any country depends on a good and well-connected road network. All other infrastructure developments, in turn, get benefited by such wide spread road network. For highway construction and maintenance world over including India, millions of tons of mineral aggregates are used. Most of the regionally and locally occurring good quality rocks, gravels and sands are the sources of road construction materials. However, depending on the locale, aggregates of minor quality may also have to be used for highway construction and maintenance some times for economic reasons, preservation of the environment and also in order to avoid large hauling distances. India has diverse geographical regions with different terrains, climate, rainfall, traffic pattern and availability of construction materials coupled with a wide range of soil types. Therefore, a standard method of design or a uniform technique of construction cannot hold good to meet the requirements of all areas and this calls for adoption of appropriate design and different technologies based on area specific conditions. Technological innovations like use of enzymes for ground improvement, waste plastics, blended bitumen, tried for cost-effective construction. It is a well-known fact that the naturally occurring materials are fast depleting because of their over-exploitation to meet the huge demand for construction of infrastructure projects. To cope with the huge demand of these materials at present and in the future, sufficient reserves have to be ensured and these reserves are non-replenish able.

.On the other hand, locally occurring materials like soil, gravel, moorum, laterite, sand, and emerging materials like mine waste; industrial slag, jute geo-textile, soil-enzymes, etc. can be effectively used singly or in combination with other materials as an alternative to conventional materials, with significant economy after studying their physical and engineering properties for their suitability in road construction. There may be situations where the existing pavements have to be dismantled. In such cases, the dismantled materials can be considered for re-use by recycling, duly supplemented with fresh materials compatible with dismantled materials. In recent times, a technology referred to as aggregate-free technology has come into use, where several environment friendly enzymes are used for improving the engineering properties of soils to minimize or almost eliminate the use of aggregates. Such materials can be tried for roads, if found suitable in Indian conditions, through field trials. Use of waste plastic in bitumen has revealed improved performance, stability, strength and fatigue life, reduction in overall rutting, and low-temperature cracking of the bituminous surfacing. For ground improvement in areas of low bearing capacity soils, marshy land and locations with drainage problems use of geo-textiles, jutes or coir is a proven technology to render positive results and cost-effectiveness especially in rural roads. In the north-eastern region, the soft soils as well as non-availability of aggregates pose difficulties for road construction. There is, therefore, a need to improve these materials. There are techniques to improve the quality of local materials. To use new materials, improved construction techniques are being practiced world over. The reinforced earth construction, use of geo-textiles, improved drainage systems, advanced technique /technology etc. are some of the techniques which can be used. It is of utmost importance to effect economy in construction with proper selection of materials, optimum input of technology and adoption of appropriate design methodology. The waste materials like fly ash, pond ash, waste copper slag, industrial slag, plastic waste etc. have been found suitable for use in different layers of roads.

However, there are situations in many states where the prescribed standards are not available at normal leads resulting in longer haulage and higher costs. If the locally available materials, including marginal and industrial waste materials are utilized, it could be possible to reduce the cost of road construction. Several types of new materials are tried to establish the efficacy of new materials in road construction. However, the use of new materials and technologies is not becoming popular owing to certain procedural constraints as well as lack of awareness and therefore appropriate steps may have to be taken for popularizing the new technologies for building better rural roads with less cost. Adoption of such technique may also result in the conservation of natural resources, energy environment.

2. Strategies for Reducing Cost of Construction of Rural Road

A typical rural road consists of compacted sub-grade, granular sub-base, base-course with graded aggregate and thin bituminous surface course in the form of pre-mix concrete with a seal coat. In order to ensure the serviceability of the road throughout the year with safety, necessary cross drainage (CD) structures, side drains, road signs, and other road furniture should be an integral part of the rural road.

The various strategies used for reducing cost of construction are listed here:

- Strategies by Moderation of Geometric Standards

- Strategies for Need Based Stage Construction
- Strategies for Use of Locally Available Material:-
  - Strategies by Using Industrial waste
  - Fly Ash for Road Construction Works
- Strategies Using Iron Slag For Road Construction
- Strategies by Using Ground Improvement Technique
  - Reducing Cost of Construction by Using Innovation in Ground Improvement Technique
  - Fujibeton as a Soil Stabilizing Agent
  - Terrazyme as a Soil Stabilizing Agent

3. Strategies by Moderation of Geometric Standards:-

Based on the recommendations of NRRDC, the widths of formation and pavement have been fixed at 7.5 m and 3.75 m respectively, though, the Rural Roads Manual permit 6 m and 3 m roadway and carriageway when the expected traffic is 100 motorized vehicles. However, most states are adopting the higher widths, regardless of the traffic volume, resulting in higher cost of construction. Therefore, it is necessary to estimate the base year traffic realistically for adopting lower geometrics to reduce the cost. Association of American State Highway and Transport roads Officials (AASHTO), USA has suggested lower geometric standards for very low volume.

4Strategies for Need Based Stage Construction:-

Under PMGSY, all roads are built with full provisions including the base and surface courses at one go. However, in many parts of the country on the new roads, connecting the habitations of lower population by link roads, the traffic expected definitely is less and a good gravel surfaced road with necessary drainage and protection systems in place can serve the rural population effectively. As and when the traffic builds up over time the roads can be strengthened through the provision of base and surface courses. This results in almost 40 per cent cost reduction in the initial stage, enabling larger coverage in a given budget. However, keeping in view the difficulties in the maintenance of gravel roads as well as the dust problem, efforts should be made to develop appropriate sealing techniques for the gravel surfaces borrowing experiences from abroad as well as R&D efforts in our country.

5 Strategies for Use of Locally Available Material:-

The situation in many states indicates non-availability of materials of requisite standards in nearby areas. Material haulage is resulting in very high cost. If the available technologies are exploited, it is possible to reduce the cost of long haulages by utilizing locally available materials, including the marginal aggregates and industrial waste material. One of the proven technologies for the use of local soil and marginal aggregates is stabilization. The stabilization process could be mechanical or chemical. Several types of stabilizing agents have proved to suit different conditions of soil and environment. Noteworthy among them are stabilization with lime or cement or a combination of lime and cement. In addition to these standard technologies, other types of technologies which are also being tried include the use of rice husk ash, phosphogypsum, and sodium chloride.
A major constraint in the use of local material lies in the procedures adopted by the field agencies and lack of awareness and exposure. It is possible to popularize the use of stabilization techniques through appropriate training and capacity building of the field engineers. In addition to the stabilization techniques, there is a large array of technologies to promote the use of industrial waste/ by products in road building. Use of the industrial waste materials—fly ash, steel and copper slag, and marble dust.

Research studies indicate that natural geo-textiles such as coir have huge potential for application on rural roads in areas where subgrade is of poor quality. Recently, a number of environment friendly enzymes have come into the markets such as fuzibeton, terrazyme, and earthzyme which are expected to provide excellent riding surfaces when mixed with in-situ or suitable borrowed soil. This technology is designed to eliminate the use of aggregates. Some field studies have shown that life cycle cost of cement concrete roads under certain

circumstances would be much less than conventional bituminous construction. This may be due to avoidance of huge routine maintenance and periodical maintenance costs in the conventional construction. Cost-effectiveness of cement concrete roads in rural areas should, therefore, be field-tested for life-cycle cost through a pilot project under PMGSY.

5.1.Strategies by Using Industrial waste:-

The waste materials like fly ash, pond ash, waste copper slag, industrial slag, plastic waste, municipal waste etc. have been found suitable for use in different layers of roads. There are suitable checks and quality tests for judging the performance of these localized materials.

5.2 Fly Ash for Road Construction Works:-

Coal is the most easily available fuel for power generation in India. Huge quantities of fly ash are produced as waste by-product of coal combustion. The present annual generation of fly ash is estimated to be about 140 million tonnes. The physical and chemical properties of fly ash depend upon the type of coal, its grinding and combustion techniques, collection, and disposal systems.
Fly ash reacts with lime in presence of moisture to form cementitious compounds. This is known as pozzolanic activity. The pozzolanic property of fly ash enables it to be used as an alternate binder in place of cement. While coarser fly ash can be used as fill material, the finer ash can be used for replacement of sand and cement in road construction works. Use of fly ash for rural road work has been covered in IRC: SP: 20 2002 and Rural Road Manual. Sub-base course can be constructed using pond ash or bottom ash replacing conventionally used moorum. Laboratory and field studies conducted in India and abroad have established that fly ash can be adopted for stabilization of sub-base/base. Fly ashes are cohesion less materials, and therefore non-plastic in nature while soil particles are generally cohesive. Mixing of soil and ash in suitable proportions improves the gradation and plasticity characteristics of the mix, thereby improving the strength. Fly ash consists primarily of oxides of silicon, aluminum iron and calcium. Magnesium, potassium, sodium, titanium, and sulphur are also present to a lesser degree. The percentages by weight of the components which are present in Fly ash are given in Table 1.

Table 1: Chemical Properties of Fly Ash

S. No.	Chemical Constituents	Percentage of constituents
1	Silica as SiO2	59.63
2	Alumina as Al2O3	31.31
3	Oxide of Iron as Fe2O3	5.11
4	Titanium oxide as TiO2	1.49
5	Lime as CaO	0.25
6	Magnesia as MgO	0.10
7	Potash as K2O	0.49
8	Soda as Na2O	0.51
9	Sulphate as SO3	0.00
10	Phosphate as P2O3	0.58
11	Loss on ignition	0.28

5.2.1 Economic Analysis of Fly Ash Treated Rural Road:-

For the cost analysis, standard govt. schedule of rates (2007) is adopted. The design specifications as per “Specifications for Rural Roads” are adopted for pavement design. The combination of fly ash, lime and existing soil give highest saving in cost than the cost of crust constructed over virgin soil. This value of saving was mentioned in the Figure 1.

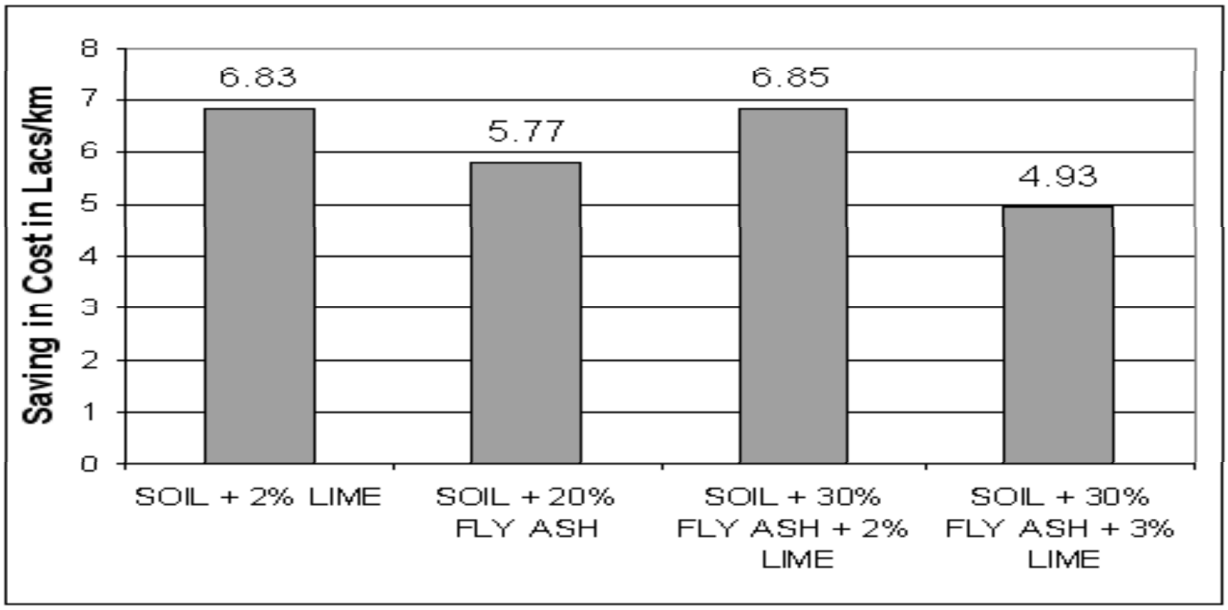

Figure 1: Relative Cost Effectiveness of Soil, Fly ash & Lime Combinations

From the design & cost comparison of sub-grade it was observed that the maximum saving was possible for 70% soil + 30% fly ash + 2% lime i.e. Rs 6.85 lakhs may be saved per km of road as compared to road using only virgin clayey soil in sub-grade. The next highest saving was for soil + 2% lime combination, i.e. 6.83 lakhs.

6. Strategies Using Iron Slag for Road Construction:-

Application of slag in road construction relies on angularity and high shear resistance of their constituent particles, which make them suitable for several pavement layers. It should be mentioned that the superior frictional resistance properties of steel slag and its resistance to permanent deformation (rutting) often overshadow the potential of this material for cracking. The sub base or subgrade soil can be lower quality because it is located at a greater distance from wearing surface, and the stresses it receives are less intense. Local materials which are the most economic can be used. Maslehuddin et al. evaluated the mechanical properties and durability characteristics of steel slag aggregate in comparison with the crushed limestone stone aggregate. The results indicated that the durability characteristics of steel slag cement were better than those of crushed limestone aggregate. Similarly, some of the physical properties of steel slag aggregate concrete were better than those of crushed limestone aggregate concrete, though the unit weight of the former was more than that of the latter.

7. Strategies by Using Ground Improvement Technique:-

One of the proven technologies for the use of local soil and marginal aggregates is stabilization. The stabilization can be mechanical or chemical and several types of stabilizing agents have proved to be suitable under different conditions of soil and environment. The soil stabilization techniques include

1) Stabilization with lime.
2) Stabilization with cement.
3) Stabilization with a combination of lime and cement

Even though specifications for soil stabilization are included in Indian Standard of specifications their adoption is not getting popular, due to problems associated in attaining homogeneity of soil-stabilizer mix in the field and achieving the desired results. The only constraint in the use of the above techniques lies on the procedures adopted in the field. It is possible to popularize the use of stabilization techniques through appropriate training and capacity building of the field engineers. Further, development of low end technology equipment, for use in the rural roads also facilitates wider use of these methods.

7.1 Reducing Cost of Construction by Using Innovation in Ground Improvement Technique:-

Recently several environmental friendly enzymes have come into the market such Fujibeton, Terrazyme and Renolith etc. Use of these products indicates minimization, elimination of the use of aggregates and is referred to as Aggregate-Free Pavement Technology. Such materials can also be tried in the rural roads construction after proving their efficacy in the Indian conditions, through series of trial projects.

7.2 Fujibeton as a Soil Stabilizing Agent:-

The Fujibeton material, is an inorganic polymer that chemically binds with all compounds, where blended with ordinary Portland cement in 1 to 3% by weight of OPC. The blended mix is called 'Fujibeton Mix', which is used for stabilization of soil that improves the engineering properties of soil. The design concept is based on the optimization of Fujibeton mix for stabilization based on unconfined compressive strength results determined on the given soil for different proportions of soil-Fujibeton mix and calculation of the thickness of the stabilization layer (Beton-Subbase) based on design CBR, wheel load and volume of traffic. The top layer of the pavement should be covered with 3 to 5 cm asphalt concrete.
The technology is advantageous not only for locations where aggregates are not available at economical rates but also for all types of soil conditions. With the use of new soil hardening agent, the material available at the construction site may be used as it is, eliminating the need for transporting of borrow soil from long distances, thus economizing and simplifying the work process. Fujibeton improves CBR of the sub-grade and does not create shrinkage cracks and is therefore highly effective for clayey/soils.

7.3 Terrazyme as a Soil Stabilizing Agent:-

Terrazyme is a natural, non-toxic liquid, formulated using vegetable extracts and accepted all over the world as a sound and resourceful road building practice, which completely replaces the conventional granular base and the granular sub base, it emphasizes on strength, performance and higher resistance towards deformation. Terrazyme is specially formulated to modify the engineering properties of soil. They require dilution in water before application. The use of Terrazyme enhances weather resistance and also increases load bearing capacity of soils. These features are particularly evident in fine-grained soils such as clay in which the formulation affects the swelling and shrinking behavior. This formulation has the ability to change the matrix of the soil so that after compaction the soil loses its ability to reabsorb water and the mechanical benefits of compaction are not lost even after water is reapplied to the compacted soil. Once the enzyme reacts with the soil, the change is permanent and the product is bio-degradable.

8. Conclusions:-

- For sub-base layer the recommended mix of 70% moorum + 15% fly ash + 15% sand + 3% lime gives 16% extra CBR as compared to the conventional mix of 70:30 moorum : sand combination. Although it costs more than the conventional mix, if used along with the recommended sub-grade layer it will still result in a cost saving of 5 lakhs /km of road on average, i.e. 20% saving in cost as compared to govt. recommended rate of Rs 22 lakhs/km.
- It meets all the requirements set forth by the MoRTH. As per IRC: 37–2001, Rs 5 lakh per km can be saved by using slag as road material. It is evident that steel plant by-products, either as such or in suitable combination, can be used in sub-base or base course layer of a road pavement.
- It meets all the requirements set forth by the MoRTH. As per IRC: 37–2001, Rs 5 lakh per km can be saved by using slag as road material. It is evident that steel plant by-products, either as such or in suitable combination, can be used in sub-base or base course layer of a road pavement.
- Terrazyme increases CBR of soil sub-grade by more than 100%. Impedes widespread occurrence of dust from loose fine material in the surface of the soil roadways and reduces cost of construction by 15-20%. The roads constructed using Terrazyme minimizes the material loss of gravel from erosion or abrasion by the traffic on the soil roadways preserving original transverse section and slopes and impedes widespread occurrence of dust from loose fine material in the surface of the soil roadways.
- The use of modified bitumen with the addition of processed waste plastic of about 8.0% by weight of bitumen helps in substantially improving the stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with marginal saving in bitumen usage.

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