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Design of Flexible Pavementsby Using Geo-Grids

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A B S T R A C T

Geo-grids have been used in pavement design for the past 25 yrs. Geo-grid reinforcement is used in permanent paved roadways in two major application areas – base reinforcement and sub-grade stabilization. In base reinforcement applications, the geo-grids are placed within or at the bottom of unbound layers of a flexible pavement system and improve the load-carrying capacity of the pavement under repeated traffic. In sub-grade stabilization applications, the geo-grids are used to build a construction platform over weak sub-grades to carry equipment and facilitate the construction of the pavement system without excessive deformations of the sub-grade.The design of geo-grids in paved and unpaved roads has been largely based on empirical design methods with some theoretical support based on bearing capacity theory. Geo-grids are widely recognized for improvement of pavement support layers (base/sub-base and/or sub-grade) through reinforcement of base/sub-base course layers in flexible pavements and unpaved roads.

However, the implementation of these proven technologies is limited by the lack of direct incorporation of materials in pavement design. When geo-grids are used in the flexible pavements and unpaved roads for improved layer support through either stabilization of soft sub-grades or reinforcement of base/sub-base course layers. In this workshop, the current design practice and the recent developments for the use of geo-grids in stabilization and base reinforcement applications will be reviewed. Upon completing this workshop, the participants will be able to restate soil conditions where geo-grids are applicable, Identify geo-grid functions in road stabilization applications, Discuss primary mechanism for reinforced base applications and locate design methods including developments in mechanistic empirical design, Identify the qualitative cost-benefit of using geo-grids in roadway sections and locate methods for quantitative evaluation, Discuss construction requirements for geo-grids in roadway application, And pavement thickness reduction..

Keywords: Geo-Grids, Paved roadways, Design

1. Introduction

1.1 Geo-Grid

A geo-grid is defined as a geo synthetic material consisting of connected parallel sets of tensile ribs with apertures of sufficient size to allow strike-through surrounding soil, stone, or other geotechnical material (coerner1998). Existing commercial geo grid products include extruded geo grids, woven geo grids, welded geo grids and geo grid composites. Extruded geo grids are formed using a polymer sheet that is punched and drawn in either one or two directions for improvement of engineering properties.

1.2 Road Necessity

As part of ongoing Andhra Pradesh Road Sector Project, yarraguntla -proddutur road is one of the geo-grid roads being implemented. The ROW has been encroached by migrant laborers (squatters and kiosks) at many locations. The Land acquisition is required only for these bypasses and at locations where geometric improvements have been proposed.

The project road passes mainly through plain areas. The land use abutting the project road are agricultural and in between settlements of 500-700-meter length of contiguous built-up areas. The project road provides vital connectivity between NH-40. The geometry of the road is generally straight except

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near built-up locations. Geometric and curve improvements have been proposed in these built-up locations, which cause displacement of title and non-title holder's families. The existing Right of Way (ROW) in this road varies from15 to 30 meters. The widening is mostly restricted within the available ROW and the land acquisition is proposed for geometrical/junction improvements and bypasses.It is noticed that at many places ROW has been encroached by rural migrant labors (mostly squatters and petty shops) working in nearby areas. The proposed geogrid road improvement envisages 2-laning with paved shoulder for yarraguntla -proddutur road

Fig 1.1: Types of geo-grids

1.3 Basic Need And Necessity Of Developing The Roads

The Need for Integrated Transport System in India, transport system comprises a number of distinct modes and services; viz. railways, roads, inland water transport, coastal shipping and air transport. Railways and roads are the dominant means of transport. In a vast country like India, it is necessary to develop various transport modes in an integrated manner to build up an efficient, sustainable, safe and regionally balanced transportation system. Each mode of transport should operate in its field of economy and usefulness, with competitive and non-discriminatory prices that are adequate to support progressive development of transport infrastructure and services. This would also enable the comparative advantages and economic efficiencies to be properly reflected in the user costs.

Recent liberalization of the Indian economy has brought home the urgency of developing an efficient transport system for increasing productivity and enabling the country to compete effectively in the world market. Adequacy and reliability of transport infrastructure and services are important factors which contribute towards the ability of the country to compete in the field of international trade and attract foreign direct investment. The Government has a major role to play in this sphere. Even in a market economy, the framework that national Government provide for the transport sector largely determines the level of cost and transport operations. It is, therefore, necessary to create a policy environment that encourages competitive pricing and coordination between alternative modes in order to provide an integrated transport system that assures the mobility of goods and people at maximum efficiency and minimum cost.

1.4 Classification of Roads

Indian roads are classified into three types namely there are

1. National Highways,
2. State Highways,
3. District and the rural roads.

The National Highways encompass a road length of only about 100,087 kms. Or 2 percent of the length of the total road system but they carry nearly 40 percent of the goods and passenger traffic. The National Highway system is the primary road grid and is the direct responsibility of the Central Government. The State Highways and District roads account for nearly 6, 00,000 kms. Or about 15 percent of the goods and passenger traffic. The construction and maintenance of these roads is the responsibility of the States. Besides there are rural roads constructed under minimum Needs Programme (MNP), Rural Landless Employment Guarantee Programme (RLEGP), National Rural Employment Programme (NREP) and Command Area Development (CAD). In all these cases, the objective of road construction is linking villages in the country.

1.5 Present Condition of the Veleru - Junction Road

At present the road passes through veleru - junction in worst condition. The road is has been uneven surfaces which are not comfortable for moving vehicles on the roads during the rains the water is staging on the road and it is creating lot of problems to the people to move from one place to another place by walk or on vehicles etc. the present condition of the veleru - junction road as shown in the fig.

Fig 1.2: Present condition of yarraguntla -proddutur road

1.6 Present Scope of the Veleru – Junction Road

Our project scope is to design the flexible pavement of the construction of the yarraguntla -proddutur road. And it was very use full for the transportation of agriculture goods, mining, moving of vehicles.

1.7 Project Impact

The proposed road will need most of the agricultural land. Because of the road pass through the yarraguntla -proddutur road in those areas most of the agricultural land occurs. But do not affect any buildings and families.

2. Literature Review

The first road on which there is some authentic record is that of **Assyrian empire** constructed by about 1900 B.C. Only during the period of the **Roman Empire**, roads were constructed in large scale and the earliest construction techniques known are of Roman Roads. Many of these roads were built of stone blocks. Hence Romans are considered to be the pioneers in road construction.

Pierre Tresaguet (1716-1796) developed an improved method of construction in France by the year 1964 A.D. The main feature of his proposal was that the thickness of construction needs to be only in the order of 30 cm. Further due consideration was given by him to sub grade moisture condition and drainage of surface water.

John Metcalfe, a Scot born in 1717, was the founder of the Institution of Civil Engineers at London. He built about 180 miles of roads in Yorkshire, England (even though he was blind). His well-drained roads were built with three layers: large stones; excavated road material; and a layer of gravel.

The first insight into today's modern pavements can be seen in the pavements of **Thomas Telford** (Scottish engineer born 1757). Teleford extended his masonry knowledge to bridge building. During lean times, he carved grave-stones and other ornamental work (about 1780). Eventually, Telford became the "Surveyor of Public Works" for the county of Salop, thus turning his attention more to roads. Telford attempted, where possible, to build roads on relatively flat grades (no more than a 1 in 30 slope) in order to reduce the number of horses needed to haul cargo. Telford's pavement section was about 350 to 450 mm (14 to 18 inches) in depth and generally specified three layers. The bottom layer was comprised of large stones 100 mm (4 inches) wide and 75 to 180 mm (3 to 7 inches) in depth. It is this specific layer which makes the Telford design unique. On top of this were placed two layers of stones of 65 mm (2.5 inches) maximum size (about 150 to 250 mm (6 to 9 inches total thickness) followed by a wearing course of gravel about 40 mm (1.6 inches). It was estimated that this system would support a load corresponding to about 88 N/mm.

The first pavements made from true **Hot Mix Asphalt** (HMA) were called sheet asphalt pavements. The HMA layers in this pavement were premixed and laid hot. Sheet asphalt became popular during the mid-1800s with the first ones being built on the Palais Royal and on the Rue St. Honore in Paris in 1858 (Abraham, 1929). The first such pavement placed in the U.S. was in Newark, New Jersey, in 1870. Sheet asphalt pavements are no longer built today.

The final steps towards modern HMA were taken by **Frederick J. Warren**. In 1901 and 1903, Warren was issued patents for an early HMA paving material and process, which he called "bitulithic". A typical bitulithic mix contained about 6 percent "bituminous cement" and graded aggregate proportioned for low air voids. The concept was to produce a mix which could use a more "fluid" binder than was used for sheet asphalt.

In 1946, two Iowa highway engineers, **James W. Johnson** and **Bert Myers**, conceptualized the slip form paver. In 1949, the Iowa Highway Department constructed the first slip formed roadway, a 3 m (9 ft.) wide, 150 mm (6 inch) thick section of county road. By placing two lanes side-by-side, a typical 6 m (18 ft.) wide county road could be built. The paver attached to a ready mix concrete truck, which would discharge its load into the paver, then pull the paver forward. In 1955, Quad City Construction Company developed an improved, self-propelled, track-mounted slip form paver capable of placing 8 m (24 ft.) wide slabs up to 250 mm (10 inches) thick. In just a few years, several equipment manufacturers were marketing slip form pavers capable of placing concrete up to four lanes wide.

Invention of **Foamed Bitumen:** More than forty years ago, Dr LadisCsanyi at the Bituminous Research Laboratory of the Engineering Experiment Station, Iowa State University successfully injected steam into bitumen to create a foaming mass. Csanyi’s invention was inspired by the abundance of ungraded marginal loess materials in his state of Iowa, and a shortage of good quality aggregate. Initially, he began experimenting with the “impact process” patented by a Swiss. Dr Csanyi discovered that, during its metastable life, the foamed bitumen could be mixed with a variety of soils to improve their properties and produce a road building material. Since then the foamed bitumen process experienced only limited application on a global scale, primarily due to the exclusive rights of the patent holders on the foam nozzles. Dr Csanyi did attempt water as a foaming agent (as well as air, gases and other foaming agents).

In 1968 Mobil of Australia acquired the patent rights for the Csanyi process. Within two years Mobil had modified the process by replacing the steam with 1% to 2% cold water that is combined with the hot bitumen in a suitably designed expansion chamber to produce the foam, which is discharged under pressure (Lee, 1981). A patent for the expansion chamber/nozzle system was granted to Mobil in Australia in 1971 and was extended to at least 14 countries. This lead to trials of the foamed bitumen process being carried out in some 16 countries in the 1970's.

3. Methodology

3.1 Construction:

Road construction requires the creation of continuous right-of-way, overcoming geographic obstacles and having grades low enough to permit vehicle or foot travel and required to meet standards set by law or official guidelines. The process is often begun with the removal of earth by digging or blasting, construction of embankments, bridges and tunnels, andremoval of vegetation (this may involve deforestation) and followed by the laying of pavement material a variety of road building equipment is employed in road building. After design, approval, planning, legal and environmental considerations have been alignment of the road is set out by a surveyor. Drainage systems must be capable of carrying the ultimate design flow from the upstream catchment with approval for the outfall from the appropriate authority to a watercourse, creek, river or the sea for drainage discharge.

A borrow pit (source for obtaining fill, gravel, and rock) and a water source should be located near or in reasonable distance to the road construction site. Approval from local authorities may be required to draw water or for working (crushing and screening) of materials for construction needs. The top soil and vegetation is removed from the borrow pit and stockpiled for subsequent rehabilitation of the extraction area. Side slopes in the excavation area not steeper than one vertical to two horizontal for safety reasons.

The completed road way is finished by paving or left with a gravel or other natural surface. The type of road surface is dependent on economic factors and expected usage. Safety improvements like Traffic signs, Crash barriers, Raised pavement markers, and other forms of Road surface marking are installed.

3.2 Flexible Pavement Types:

Basically, flexible pavement types can be categorized into two groups,

- Normal Flexible Pavement
- Reinforced (geo-grid) flexible Pavement

Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "flexing".

On the other hand, Reinforced flexible pavements are constructed with a placing of geogrid between the any two layers of the total pavement. Such pavements are substantially "stiffer" than normal flexible pavements due to the high modulus of elasticity of the geo-grid material. .

Flexible pavements generally require some sort of maintenance or rehabilitation every 10 to 15 years. Reinforced flexible pavements, on the other hand, can often serve 20 to 40 years with little or no maintenance or rehabilitation.

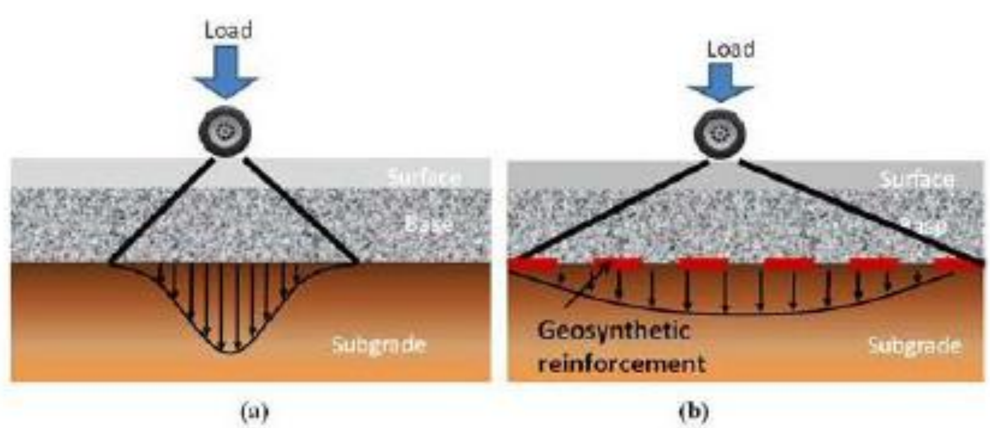

Fig 3.2: Load distribution without and with geo-grid in flexible pavement

Each of these pavement types distributes load over the sub grade in a different fashion. Reinforced flexible pavement, because of geo-grid high elastic modulus (stiffness), tends to distribute the load over a relatively wide area of sub grade. Flexible pavement uses more flexible surface course and distributes loads over a smaller area. It relies on a combination of layers for transmitting load to the sub grade.

This project completely deals with Reinforced Flexible Pavements. Almost all the highways and expressways are flexible. Hence, the analysis in this project only refers to reinforced flexible pavements.

The typical cross-section of a reinforced flexible pavement consists of several layers. They are as follows:

- Original Ground Level (OGL)
- Low Embankment
- High Embankment
- Sub-Grade

- Granular Sub-Base (GSB)
- Wet Mix Macadam (WMM)
- Dense Bitumen Macadam (DBM)
- Bitumen Concrete (BC)

3.3 PROPERTIES OF EACH LAYER:

3.3.1 Original Ground Level: It is the original ground surface before any work starts.

3.3.2 Low Embankment: Embankment consists of a number of soil layers. It is used to increase the level of pavement. Low embankment is the one which has a maximum height of 3m. Low embankment should have the following properties:

- Minimum compaction of 95%
- Minimum Dry Density of 1.55gm/cc
- Maximum Free swell index of 50%
- Minimum CBR of 10%
- Maximum Liquid limit of 40%
- Maximum Plasticity index of 18%

3.3.3 High Embankment: High embankment is the one in which height is above 3m. High embankment should have the following properties:

- Minimum compaction of 97%
- Minimum Dry Density of 1.63gm/cc
- Maximum Free swell index of 50%
- Minimum CBR of 10%
- Maximum Liquid limit of 40%
- Maximum Plasticity index of 18%

3.3.4 Sub-Grade: Sub-grade or Soil Sub-grade is a soil layer above embankment. The thickness of this layer is 0.25m.

3.3.5 Granular Sub-base: GSB is a layer of mixed aggregates. It consists of dust, 40mm aggregates and 10mm aggregates. The thickness of this layer is 0.2m. GSB should have the following requirements:

- Minimum Compaction of 98%
- Maximum Water Absorption of 2%
- Minimum CBR of 30%
- Maximum Liquid limit of 25%
- Maximum Plasticity index of 6%
- Minimum 10% fines of 50KN

3.3.6 Wet Mix Macadam:WMM is a mixture of 40mm, 20mm, 10mm aggregates, dust and water. It is constructed in 2 layers. The thickness of each layer is about 0.125m. The total thickness is 0.25m. WMM should have the following properties:

- Minimum Compaction of 98%
- Maximum Water Absorption of 2%
- Maximum AIV of 30%
- Maximum Liquid limit of 25%
- Maximum Plasticity index of 6%
- Maximum FI&EI of 30%

3.3.7 Dense Bitumen Macadam: DBM is constructed in 2 layers. The 1st layer should have minimum bitumen content of 4 to 4.5%. The 2nd layer should have minimum bitumen content of 4.5 to 5%. The aggregates used for this layer are 40mm, 20mm, 10mm and dust, lime or cement. Other requirements of DBM are:

- Minimum Compaction of 98%
- Maximum Water Absorption of 2%
- Maximum AIV of 27%
- Maximum Plasticity index of 4%
- Maximum FI&EI of 30%

4. Results

In the design purpose we have to required only soil tests. Because of in these project we have to find out only thickness of the pavement. (I.e. means pavement thickness difference between the normal pavement to the reinforced flexible pavement)

4.1 CALIFORNIA BEARING RATIO TEST (CBR):

CBR test for normal clay (without geo-grid)

PENETRTION (in mm)	PROVING RING	LOAD ON PLUNGER (in kg)
0.0	0	0
0.5	8	15.2
1.0	14	26.6
1.5	17	32.3
2.0	24	38
2.5	29	55.1
3.0	30	57
4.0	32	60.8
5.0	36	68.4
7.0	44	83.6
10.0	52	98.9
12.0	56	106.4

CBR% = (load carried by 50%sample at defined penetration level) / (load covered by crushed Stones at the above penetration level)*100

CBR value at 2.5mm penetration=55.1/1370*100 =4.0%

At 5.0mm penetration=68.4/2025*100 =3.32%

CBR2.5>CBR5.0

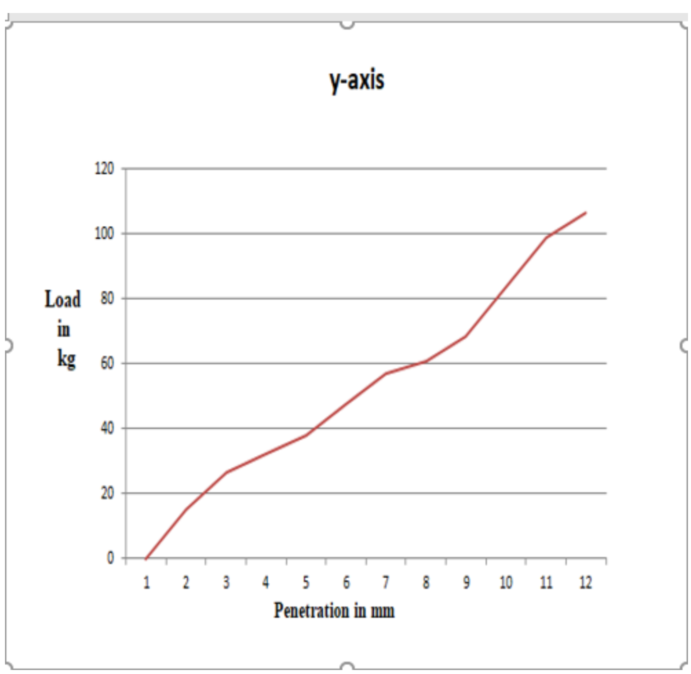

Fig 4.1 CBR test for reinforced clay (with geo-grid)

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Position of the geo-grid

Penetration in mm	Roving Ring				Load on Plunger			
	0.2 H	0.4H	0.6 H	0.8 H	0.2 H	0.4H	0.6 H	0.8 H
0.0	0	0	0	0	0	0	0	0
0.5	22	19	13	10	41.8	36.1	24.7	19
1.0	35	28	20	18	66.5	53.2	38	34.2
1.5	44	37	29	26	83.6	70.3	55.1	49.4
2.0	56	46	36	32	106.4	87.4	68.4	60.8
2.5	65	58	44	40	123.5	110.2	83.6	76
3.0	70	62	47	45	133	117.8	89.3	85.5
4.0	74	69	50	49	140.6	131.1	95	93.1
5.0	80	73	55	52	152	138.7	104.5	98.8
7.0	85	79	59	55	161.5	150.1	112.1	104.5
10.0	90	81	62	58	171	153.9	117.8	110.2
12.0	91	85	65	60	172.9	161.5	123.5	114

Results of CBR tests for Different positions of geo-grids :

Sr.no	Position of geo-grid from top of specimen	Un-soaked CBR values
1	No geo-grid	4.0
2	0.2H	9.0
3	0.4H	8.04
4	0.6H	6.10
5	0.8H	5.54

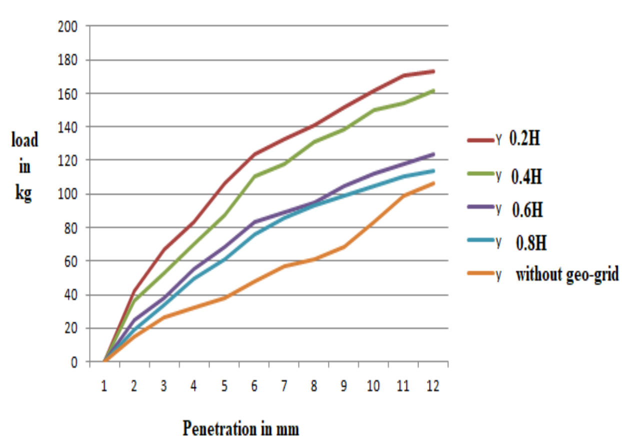

Fig 4.2 Cbr Graph for Reinforced Clay at Different Depths of Geo-Gridpositions

5. Conclusion

- Reinforced Flexible pavements are more durable compared to the normal flexible pavements.
- Reduction in maintenance and rehabilitation operations, this pavement is cheaper than the normal flexible pavement.
- These pavements reduce the thickness of the layers as compared to the normal flexible pavements.
- These pavements are durable, safe and long lasting compared to the normal flexible- pavements.
- These pavements are fully recyclable.
- Reinforced Flexible pavements provide smooth, safe surfaces and minimize fuel consumption
- These pavements are earth-quake resistance structures.

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