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Research Article

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Optimization of Jute Geotextiles in Pavement Design –State of the Art

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Abstract:

Permeable textiles, used in association with geotechnical engineering related material, as an integral part of a man made project is called GEOTEXTILES. It has the ability to filter, reinforce, protect and drain. JUTE, a wholly renewable, bio degradable, naturally available geotextile is produced in abundance in India. Design of pavement using JGT is a boon to rural roads which enhances the aesthetic appearance also with benefits in lifecycle increment. Fortunately the economic aspect also in acceptance range. Coupled with the software analysis of designing a JGT incorporated road and comparing the ordinary flexible pavement, jute geotextile incorporated flexible pavement last longer than the usual roads.

Keywords: Geotextile, Reinforcement, Aesthetic, Eco-friendly, Long life-cycle.

I. INTRODUCTION

Transportation contributes to economic, industrial, social and cultural development of any country. There are different modes of transportation such as railways, waterways and airways. But roadways are the only mode which could give maximum service to all. Even all the other three modes have to depend on roadways to reach their respective terminals. There are certain foreign materials being incorporated in pavements to make it further economical and for strengthening. One of the economical and eco-friendly product that is incorporated in a flexible pavement is JUTE GEOTEXTILE. Geotextile, particularly jute geotextiles are recently emerging technologies in geotechnical and bio-engineering fields. The use of textiles in the construction industry is not new. At present there is a huge global demand for suitable jute geotextiles to be used in the civil engineering and construction industries.

1.1 Jute Geotextile

Jute geotextile is one of the most important diversified jute products with a potentially large scale application. It can have several applications as: soil erosion control, vegetation consolidation, agro-mulching, reinforcement, and protection of riverbanks & embankments, land reclamation and in road pavement construction.

The demand for jute geotextiles is increasing in various parts of the world. However, absence of adequate awareness and standards and specifications seem to be affecting the possible expansion of the market.The distinguishing features that make geotextiles more eco-friendly are:

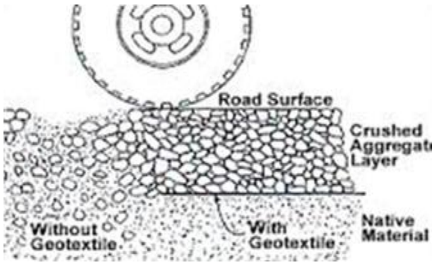
- High moisture absorption capacity
- Flexibility

Advantages of jute geotextiles

- Abundant availability
- Superior drapability
- Greater moisture retention capacity
- Lower costs compared to synthetic geotextiles
- Ease of installation

1.2. JGT in road construction

In all the field applications in roads, it has been observed that sub-grades, despite being expansive, experienced increase in CBR in the range of 1.5 to 3.0 times the control value. As soil consolidation is a time-dependent process, with the passage of time CBR shows a sustained rise even after a period of 8/9 years. For example a PMGSY road, Andulia to Bairatala at 24 Parganas(N) was constructed with JGT . BESUS evaluated the performance of the study. The Subgrade CBR was increased from 2.22 to 12 % within a span of 18 months. Void ratio and compression index of It was observed that the sub-grade soil registered a downward trend while its dry density increased. In most of these road applications, woven JGT having tensile strength of 20 kN/m to 25 kN/m were used. In busy and heavy roads use of woven JGT of higher tensile strength (30 kN/m) and above may be called for.

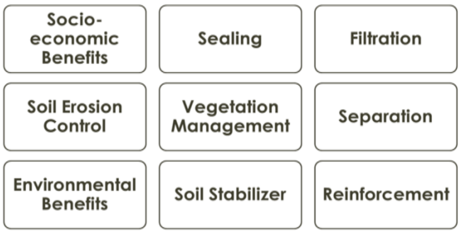


II. JUTE GEOTEXTILE

Jute, known as a golden fibre for its gold-like texture, is a unique textile grade lingo-cellulosic fibre. Its main chemical constituents are alfa cellulose (62 %) , hemicelluloses (24 %) , lignin (12%) and others (2 %). Its high tenacity (3 – 5 g/d), low elongation at break(1.4%) and high moisture content (13%) at 65% RH hold an edge over other fibresused for manufacturing geotextiles, Jute fibre which is well comparable with that of man-made fibres like, polyester and polypropylene etc. while elongation at break of jute is much less than that of man-made fibres which are advantageous features for jute. Thermal property of jute is also an advantageous feature as compared to the man-made fibres**.**

2.1. Multifunctions of Jute Geotextiles

Geotextiles are not a single commodity. These applications are generally categorized as: soil stabilizer, application at the interface of the formation of soil and the track back to minimize pumping of fine soil into granular materials, consolidation of soil through filtration and drainage by filter cake formation, application as erosion control, reinforcement of civil construction, moisturization, protection from rain, wind, light and cold etc. In fact geotextiles are multi-functional and location specific in nature. Bioengineering/agro mulching of natural fibrous materials are most effective due to their biodegradability, echo-compatibility and improvement of soil fertility and texture. In addition to erosion control, they also facilitate vegetative growth. Geotextiles are used in a variety of applications, including ground separation, earth reinforcement, slope stabilization, groundwater filtration, drainage, soil erosion control and vegetation management.



2.2. Jute and its types

Methods for producing different types of jute-geotextiles have already been devised by blending jute with other natural fibers with definite proportions and fabricated in definite pattern. Jute-geotextiles are further treated with locally available chemicals according to need and life span. They can be made
biodegradable on a longer time-frame and water resistant in nature, particularly suitable for rain fed, flood affected climatic condition. Two varieties of jute fibres like white and tossa are available in the country. In India average annual production of jute is of the order of 1.8 million MT with sacking bag being the potent product. Jute industry in India is one of the oldest agro-industries in the world. More than 0.7 million people are dependent on jute production, its manufacture and marketing for their livelihood. Ingress of man-made polymers is posing threats to the jute industry which is why diversification of jute products has become an imperative necessity. Indian Jute Industries' Research Association (IJIRA), a premier R & D organization in India has developed a number of jute diversified products including Jute Geotextile (JGT) through extensive research and development work utilizing the intrinsic properties of jute fibres such as, high initial tensile strength, low extensibility, high water absorbency, excellent drapability and spinnability.

Properties		Values					
		JG800	JG750	JG670	JG560	JG500	JG235
Thickness (mm)		1.72	1.70	1.43	1.21	1.20	0.85
Mass per Unit Area (gsm)		800	750	670	560	500	235
O_{95} (mm)		0.425	0.425	0.150	0.075	0.850	0.850
Tearing Strength (kN)	Machine Direction	0.191	0.108	0.090	0.180	0.180	0.0765
	Cross Machine Direction	0.179	0.179	0.135	0.198	0.119	0.099
CBR puncture strength (kN)		2.850	2.644	1.314	1.422	1.286	0.671
Permittivity (S^{-1})		10.2×10^{-3}	9.5×10^{-3}	10.1×10^{-3}	6.9×10^{-3}	16.1×10^{-3}	11.0×10^{-3}
Transmissivity (m^2/S)		6.9×10^{-6}	5.68×10^{-6}	5.4×10^{-6}	16.0×10^{-6}	9.11×10^{-6}	21.1×10^{-6}

III. COMPARISON OF JUTE WITH MAN MADE FIBERS

TABLE 1

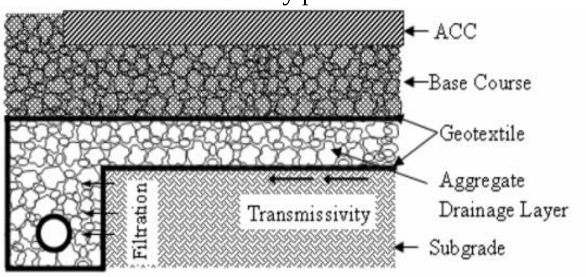
Sl. No.	Properties	Jute	Polyester	Polypropylene
01.	Specific gravity	1.48	1.38	0.91
02.	Tenacity, g/d	3 to 5	2 to 9.2	2.5 to 5.5
03.	Breaking Elongation, %	0.8 to 2	7 to 37	17
04.	Elastic recovery, %	75 to 85	57 to 99	75 to 95
05.	Moisture content, at 65% R.H. and 27^0C.	12.5 to 13.8	0.4	0.01
06.	Effect of heat	It does not melt. Up to 180^0C there is no major wt. loss and tenacity loss. However hemi cellulose degrades around 293^0C and other constituents at higher temperature.	Sticks at 180^0C and Melts at 230^0 – 240^0C	Softens at 143^0 – 154^0C, melts at 160^0C & decomposes at 288^0C

IV. FLEXIBLE PAVEMENT

The flexible pavement are built with number of layers. In the design process, its is ensured that under the application of load none of the layers is overstressed. The maximum intensity of stresses occur in the top layer of the pavement. The magnitude of stresses reduces at the lower layers. Hence the superior pavement material is used in top layers of the flexible pavement.

Pavement performance can be largely attributed to the performance of its foundation, which is comprised of the subgrade and base layers. Base and subgrade layers must provide adequate and moisture resistant strength and modulus, in addition to durability and stability.

Frequently, in situ soils and local base materials do not meet project-specific requirements. Texas also has some of the most expansive soils in the country, which cause distresses in many pavements around the state.



Currently, a large portion of pavement construction consists of rehabilitating existing roads. These roads frequently contain subgrade or base material layers that are inadequate for current traffic loading demands. Shortages of high quality soil-aggregate sources are becoming more and more common statewide.

In order to achieve specified properties, subgrade, select fill, and base materials frequently require treatment with additives such as asphalt, cement, fly ash, and lime. Each of these materials must be properly designed to determine the most appropriate additive to achieve the desired improvement.

4.2. Test carried out on the pavement material

a) AGGREGATE CRUSHING TEST

The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces.

sno	Details of sample	T1	T 2	T 3
1	Total weight of aggregate(w1)	0.67	0.75	0.63
2	Weight of aggregate passing 2.36mm sieve after testing(w2)	0.05	0.04	0.04
3	Weight of aggregate retained 2.36mm sieve after testing(w3)	0.61	0.66	0.59
4	w1-w2+w3	1.23	1.36	1.18
	Aggregate impact value=(w2/w1)*100	8.05 %	6.49 %	7.71 %

The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.
Apparatus
The apparatus as per IS: 2386 (Part IV) – 1963 consists of:
(i) A testing machine weighing 45 to 60 kg and having a metal base with a painted lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.
(ii) A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm. .

Procedure
The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.
(i) Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates
passing through 12.5mm sieve and retained on 10.0mm sieve comprises the testmaterial.
(ii) Pour the aggregates to fill about just 1/3 rd depth of measuring cylinder.
(iii) Compact the material by giving 25 gentle blows with the rounded end of thetamping rod.
(iv) Add two more layers in similar manner, so that cylinder is full.
(v) Strike off the surplus aggregates.
(vi) Determine the net weight of the aggregates to the nearest gram (W).
(vii) Bring the impact machine to rest without wedging or packing up on the level plate,block or floor, so that it is rigid and the hammer guide columns are vertical.
(viii) Fix the cup firmly in position on the base of machine and place whole of the testsample in it and compact by giving 25 gentle strokes with tamping rod.
(ix) Raise the hammer until its lower face is 380 mm above the surface of aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.
(x) Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sievesuntil no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1 gm. Also, weigh the fraction retained in the sieve.

Result
The impact value=7.41%

RECOMMENDED VALUES

Classification of aggregates using Aggregate Impact Value is as given below:

Aggregate Impact Value	Classification
10 – 20%	Strong
20-30%	Satisfactory for road surfacing
>35%	Weak for road surfacing

b) DUCTILITY TEST ON BITUMEN
Procedure
i) Completely melt the bituminous material to be tested by heating it to a temperature of 75 to 100oC above the approximate softening point until it becomes thoroughly fluid. Assemble the mould on a brass plate and in order to prevent the material under test from sticking, thoroughly coat the surface of the plate and the interior surfaces of the sides of the mould with a mixture of equal parts of glycerine and dextrin.
While filling, pour the material in a thin stream back and forth from end to end of the mould until it is more than level full. Leave it to cool at room temperature for 30 to 40 minutes and then place it in a water bath maintained at the specified temperature for 30 minutes, after which cut off the excess bitumen by means of a hot, straight-edged putty knife or spatula, so that the mould is just level full.
ii) Place the brass plate and mould with briquette specimen in the water bath and keep it at the specified temperature for about 85 to 95 minutes. Remove the briquette from the plate, detach the side pieces and the briquette immediately.
iii) Attach the rings at each end of the two clips to the pins or hooks in the testing machine and pull the two clips apart horizontally at a uniform speed, as specified, until the briquette ruptures. Measure the distance in cm through which the clips have been pulled to produce rupture. While the test is being done, make sure that the water in the tank of the testing machine covers the specimen both above and below by at least 25mm and the temperature is maintained continuously within ± 0.5oC of the specified temperature.

Result
Within the acceptable limit of 30cms in briquette mould

V. PAVEMENT CONSTRUCTION

5.1. DESIGN PROCESS

The flexible pavement design consist of the following stages:
Step 1: Initial assessment
The design of the pavement is done collecting the required data such as traffic compilation and traffic growth rate.
Step 2: Sub-base compaction
The soil is compacted using compactors or rollers to achieve a leveled surface. It is often the main load bearing layer of the pavement.
Step 3: Base course
This layer consist of a mixture of high quality aggregates of specified size and bitumen which is been effectively spread and compacted.
Step 4: Weathering course
The suitable weather course material is used to prevent wear and tear.

5.2. PRIME COAT

For flexible pavements, the graded subgrade or the top granular base layer may be prepared with a prime coat. A prime coat is a sprayed application of a cutback (M-30 or M-70) or emulsion asphalt applied to the surface of untreated subgrade or base layers. The prime coat serves several purposes:

- fills the surface voids and protect the base from weather
- stabilizes the fines and preserve the base material
- promotes bonding to the subsequent pavement layers.

5.3. TACK COAT

A tack coat material can be a PG binder or an emulsion layer applied between the pavement layers to promote bonding. Adequate bonding between constructed lifts (especially between the existing road surface and an overlay) is critical for the constructed pavement structure to behave as a single unit and provide adequate strength. If adjacent layers do not bond to one another they essentially behave as multiple independent thin layers - none of which are designed to accommodate the anticipated traffic-imposed bending stresses. Inadequate bonding between layers can result in delamination (debonding) followed by longitudinal wheel path cracking, alligator cracking, potholes, and other distresses such as rutting that greatly reduce pavement life.

5.4. FOUNDATION

As with any pavement structure, quality begins at the foundation level. These structures must have a uniform, stiff, durable foundation that will adequately support the premium materials placed above. To establish the appropriate type and level of stabilization according to established test procedures, a geotechnical investigation of the underlying soils should be performed. Where stabilization of the subgrade is impractical, a high quality granular base, cement-treated base, or other engineered foundation should be used.

5.5. MIX PLACEMENT AND COMPACTION

Mix placement and compaction are the two most important elements in pavement construction. Mix placement involves any equipment or procedures used to place the delivered on the desired surface at the desired thickness. Mix placement can involve complicated asphalt paver operations or simple manual shoveling.
Compaction is the process by which the volume of air in a mixture is reduced by using external forces to reorient the constituent aggregate particles into a more closely spaced arrangement. This reduction of air volume in a mixture produces a corresponding increase in unit weight, or density. Numerous researchers have stated that compaction is the greatest determining factor in dense graded pavement performance.

VI. IRC METHOD OF DESIGN

Indian roads congress has specified the design procedures for flexible pavements based on CBR values. The Pavement designs given in the previous edition IRC:37-1984 were applicable to design traffic upto only 30 million standard axles (msa). The earlier code is empirical in nature which has limitations regarding applicability and extrapolation. This guidelines follows analytical designs and developed new set of designs up to 150 msa.
Scope
These guidelines will apply to design of flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/ MOST standards. These guidelines apply to new pavements.

Design traffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life

3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Initial traffic

Initial traffic is determined in terms of commercial vehicles per day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tonnes or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts (ADT). In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.

Traffic growth rate

Traffic growth rates can be estimated (i) by studying the past trends of traffic growth, and (ii) by establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted.

Design life

For the purpose of the pavement design, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and other categories of roads for 10 to 15 years.

Vehicle Damage Factor

The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the axle configuration, axle loading, terrain, type of road, and from region to region. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions.

Vehicle distribution

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

Two-lane single carriageway roads

The design should be based on 75 % of the commercial vehicles in both directions.

Pavement thickness design charts

For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10 %. The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing.

VII. TWO WAY LANE DESIGN

A two-lane expressway is an expressway with only one lane in each direction, and usually no median barrier. It may be built that way because of constraints, or may be intended for expansion once traffic volumes rise. The term super two is often used by road geeks for this type of road, but traffic engineers use that term for a high-quality surface road. Most of these roads are not tolled.

The empirical formula to calculation of msa

Nș=365*A*[(1+r)^n -1]*Fr

N = the cumulative number of standard axles to be catered for in the design in terms of msa

A = Initial traffic in the year of completion of construction in terms of the no. of commercial vehicles per day.

D = Lane distribution factor

F = vehicle damage factor

n = Design life in years

r = Annual growth rate of commercial vehicles .

DATA

- Initial traffic in the year of completion of construction = 400 CVPD (sum of both directions)
- Traffic growth rate = 7.5 %
- Design life = 15 years
- Design CBR of subgrade soil = 4%.

SOLUTION

Distribution factor = 0.75

N =[365 ×(1 + 0.075)^15 − 1) 0.075× 400 × 0.75 × 2.5]/0.075

= 7200000

= 7.2 msa

Total pavement thickness for CBR 4% and traffic 7.2 msa from IRC:37 2001 chart1 = 660 mm

- Bituminous surfacing=60mm
- Base course thickness=245mm
- Jute layer=50mm
- Sub base course=305mm

The design procedure given by IRC makes use of the CBR value, million standard axle concept, and vehicle damage factor. Traffic distribution along the lanes are taken into account. The design is meant for design traffic which is arrived at using a growth rate.

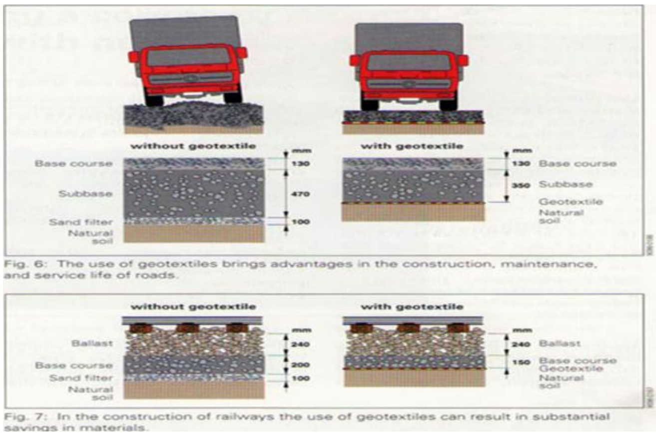


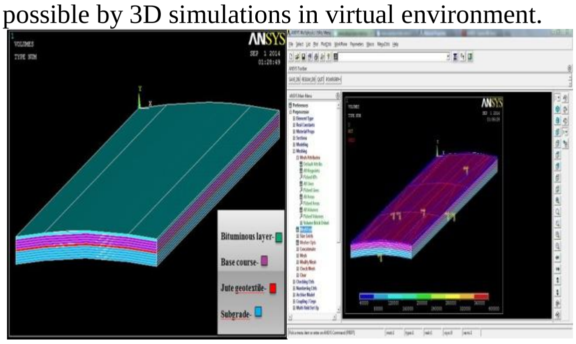
Fig. 6: The use of geotextiles brings advantages in the construction, maintenance, and service life of roads.

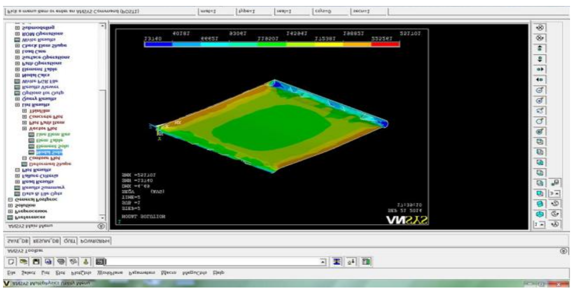
Fig. 7: In the construction of railways the use of geotextiles can result in substantial savings in materials.

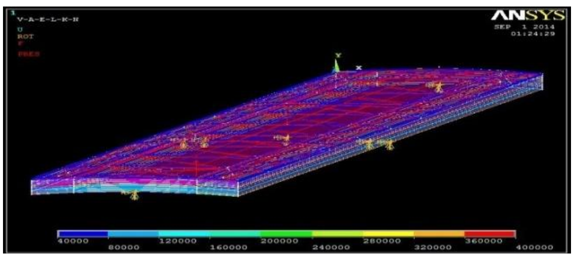
VIII. ANSYS SOFTWARE

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.







The stress distribution pattern using ANSYS software shows that there is regular uniform distribution of base pressure due to the rigidity between layers, maintained by various jute layers in-between, thereby preventing intermixing of various layers. This is mainly used for validation purposes.

IX. FAILURES OF FLEXIBLE PAVEMENT

Road maintenance is one of the important components of the entire road system. Various types of failures in pavement ranging from minor and localized failures to major and general failures do take place on roads. The failures may occur one or combination of several causes.

FATIGUE FAILURE

- Is due to the built up of tensile strain at the bottom of pavement layer.
- Pavement is considered failed if 20% of the surface has cracked.

RUTTING FAILURE

- Is due to the buildup of excessive compressive strain at the top of subgrade layer.
- Pavement is considered failed if it exhibits a rut depth of 20mm.

9.1. GENERAL CAUSES OF FAILURE IN PAVEMENT

- defect in quality of material used.
- defect in construction method and quality control during construction.
- inadequate surface or subsurface drainage.
- settlement of foundation.
- environmental factors.

X. FAILURE DESIGN FOR FATIGUE

The formula for calculating fatigue is

Nƒ=K3 [1/&]^k1 x [1/E]^k2

Coefficients (from shell hand book)

- K1=0.0685
- K2=5.671
- K3=2.363

Result=0.3261

Permissible limit is between 0.25 to 0.4m

Hence it is safe.

COST COMPARISON

For 1km Flexible pavement

course material= Rs.300 per sq.m

Bitumen= Rs.182.57 per sq.m

total cost varies from 4.8 to 5 lakhs.

For 1km JGT Road

JGT for 1km= Rs.89.376 per sq.m

Nearly 5.5 lakhs

The increase in cost is compensated by increase in life cycle and low maintenance cost of the pavement

XI. CONCLUSION

Hence a flexible pavement incorporated with JGT was designed and stress distribution was analysed using ANSYS. The failure criteria of the pavement was also designed. The cost comparison of normal pavement and JGT pavement was done. From the entire analysis it was found that rainwater collected by the roadside drained faster than usual in JGT roads. These roads will be stronger and last longer than normal roads. They will not develop holes after the monsoons . By using jute, a road's life can be increased by three to four years. When it does degenerate, it will become a part of the soil as it is biodegradable. Since no new technology or industrial infrastructure is required for the preparation of JGT, its availability is more. Production is also based on existing manufacturing process. It addresses soil related problems and strengthens roads. JGT deserves special encouragement from the decision-makers for its eco compatibility and competitive price.

REFERENCES

[1] IRC 37:2001- Indian road congress code for design of pavement
[2] IS:2386Part 1V-1963- aggregate selection and test for aggregate in road work.
[3] Highway engineering by S.K.Garg
[4] C.E.G.Justo published by NEM CHAND BRO.
[5] Highway engineering by S.C. Rangwala published by Charotar Publishing House Pvt.
[6] Highway design and construction by A.G.Bruce.
[7] Choudhury, P. K. Chatterjee, P. K. and Dutta, U. 1999 A Low Tech. Approach for Forests. 1 st Asia – Pasific Conference on Water & Bioengineering for erosion control & slope stabilization.

