REHABILITATION OF NATIONAL HIGHWAY DAMAGED BY RAIN USING GEOSYNTHETICS IN HILLY TERRAIN – A CASE STUDY

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ABSTRACT

Geosynthetics are increasingly used in the design of flexible paved pavement sections. One style of geosynthetics best suited for pavement applications is the geocell. Geocells are unique three-dimensional rhomboidal cellular confinement systems whose characteristics provide additional rigidity to the pavement structure. The walls of the geocells are perforated to effectively facilitate drainage. Incorporating the infilled geocell within any granular component of a flexible pavement on a weak subgrade improves the resilient modulus of the layer. This reduces the strains at critical point between the base course and the bituminous layers and at the subgrade level. Hence pavement thickness can be reduced and / or the life of the pavement can be extended according to the designer's requirements. The authors present a case study where geocells have been effectively used in reconstruction of the National Highway NH-44 traversing over hilly and forested terrain across the Assam – Tripura border, which was destroyed during torrential rain since March 2016 and to-and-fro traffic was badly affected. The affected section was between Malidoor (Assam-Meghalaya border) and Churaibari (Assam-Tripura border). NH-44 is the only road connecting Tripura to the rest of country. The CBR of the subgrade along the damaged section was reported as low as 0.50% with traffic as high as 20msa. Rehabilitation was designed and executed with the judicious use of geocells, woven and Non-woven geotextiles. The work was executed jointly by PW (Buildings and NH) Division of Assam and Strata Geosystems (India) Pvt. Ltd. This Paper records the design, construction and performance of the highway reconstructed with geocells and geotextiles**.**

BACKGROUND

The National Highway NH-44 is a major artery for the North East India. The stretch between Malidoor at the Assam–Meghalaya State border and Churaibari at the Assam–Tripura State border is crucial for Tripura. Because of Tripura's peculiar geography, NH-44 is its crucial life-line for supplies and victuals, the only land connect with the rest of the country. Satellite imagery of the location is shown in Fig. 1.

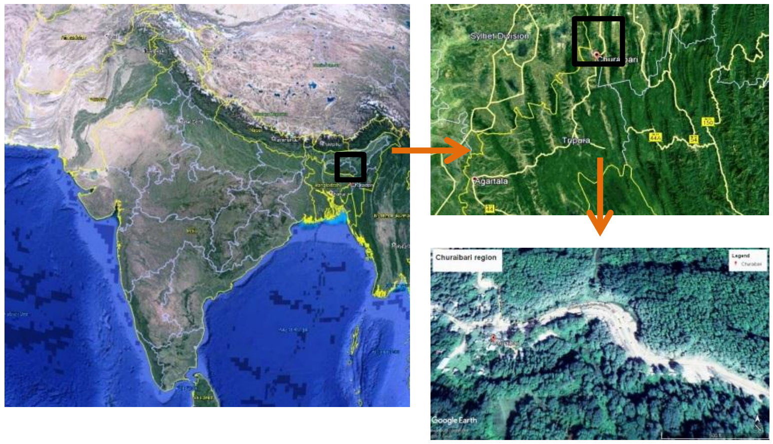

FIGURE 1 Satellite imagery of the location

PROBLEM

The highway was damaged near Churaibari on the Assam side of the border. The subgrade of the highway is highly plastic but weak clayey soil. The area traverses forested and undulating terrain and drainage was an issue which was compounded by subgrade of low permeability. There were heavy downpours in the month of March 2016, which completely damaged the stretch of about 1500m and made it was difficult for vehicles to ply. Figure 2 shows the extent of the damaged highway. Conventional repairs proved unsuccessful. With the bottleneck of stranded vehicles the situation turned chaotic and untenable with blockage of all goods to Tripura and virtual isolation from the rest of the country.

FIGURE 2(a) Damaged stretch through the dense forest

FIGURE 2(b) Actual site condition

OBJECTIVE

In view of Strata Geosystems (India) Pvt. Ltd.'s known expertise in geosynthetics and pavements, the Assam PW (Buildings & NH) Department called upon Strata and appraised it of the problem in June 2016. By then the issue was a matter of serious concern with the Central Government, with the prices of essential commodities including fuel and food items skyrocketing even beyond imagination. There were two essential issues to be addressed.

a) Drainage of the pavement section and its subgrade;

b) Strengthening the pavement section.

Both these concerns were deliberated upon by Strata while recommending StrataWeb® geocells within the pavement section. The perforated geocells when infilled with granular material provide an excellent drainage medium and prevent build-up of pore water pressures.

Owing to logistics problems created by the rains, the geosynthetic materials including StrataWeb® geocells could reach the affected site only by the end of July 2016. However the rehabilitation work commenced immediately, to be completed within fifteen days, adequately enough for free flow of traffic.

DESIGN ANALYSIS

On the basis of the soil test carried out at the site by the Assam PW (Buildings & NH) Division officials, the following parameters highlighted in Table 1 were considered in design analysis.

TABLE 1 Parameters considered in analysis

Sr. No.	Parameters	Units	Values
1	Subgrade CBR	%	0.50
2	Traffic	MSA	20
3	Internal friction of the geocell infill material passing through 40mm down IS sieve	°	≥32

The flexible pavement was modeled as an elastic multilayer structure. Accordingly stresses and strains are computed at critical locations mentioned in Fig. 3.

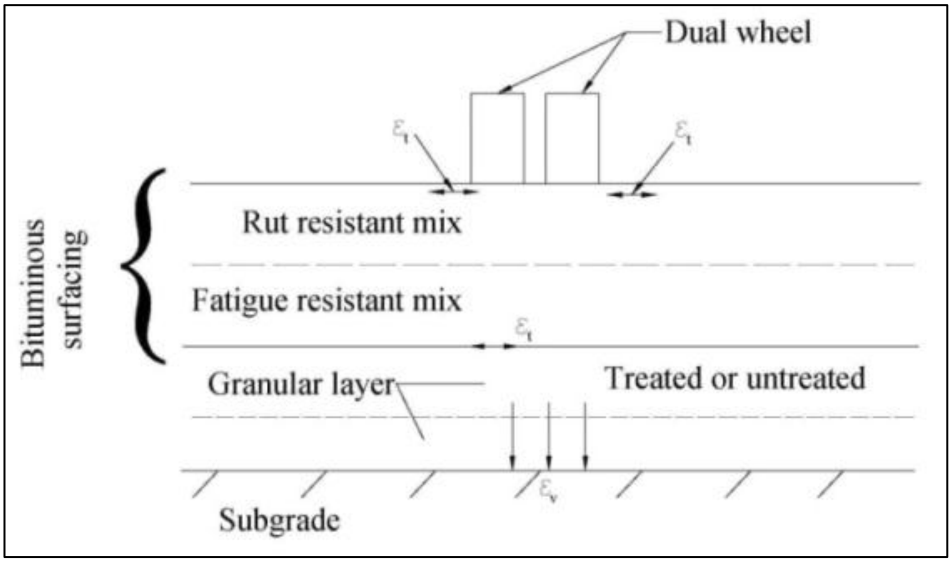

FIGURE 3 Critical locations for computing strain values

Generally thicknesses of the pavement and its various components are conventionally determined using IRC: 37-2012 "Guidelines for the Design of Flexible Pavements" [1]. The objective was to strengthen the pavement section. This objective could be achieved with the appropriate application of geocells. Several researchers have confirmed the efficacy of geocells in pavement construction [2-3]. However, there is paucity of case studies for evaluating the performance of geocells [4].

With the proposed geocells, the possibility of rutting would be greatly reduced with the added advantage of providing an economic section. In case of flexible pavements, excess horizontal tensile strains cause reflective cracking over the bitumen surface and vertical strains causes rutting. Hence it is significant to evaluate the horizontal strain at the bottom of bituminous layer and vertical strain at the granular sub-base / sub-grade junction only.

To compute limiting strain for a given traffic is calculated based on following equations for fatigue life and rutting life for 80 % and 90% of reliability.

$$N_f = 2.21 \times 10^{-4} \times \left(\frac{1}{\varepsilon_t}\right)^{3.89} \times \left(\frac{1}{M_R}\right)^{0.854} \quad (1)$$

$$N_r = 4.1656 \times 10^{-08} \times \left(\frac{1}{\varepsilon_v}\right)^{4.5337} \quad (2)$$

$$N_f = 0.711 \times 10^{-4} \times \left(\frac{1}{\varepsilon_t}\right)^{3.89} \times \left(\frac{1}{M_R}\right)^{0.854} \quad (3)$$

$$N_r = 1.41 \times 10^{-08} \times \left(\frac{1}{\varepsilon_v}\right)^{4.5337} \quad (4)$$

where,

N_f and N_r are the design fatigue life and rutting life in msa respectively.

ε_t and ε_v are horizontal tensile strain and vertical subgrade strain respectively.

M_R is the resilient modulus of the bituminous layer.

Based on the equations 1-4 charts were prepared for corresponding limiting strains values v/s different design traffic in msa (traffic ranging from 1msa to 150msa). These charts are shown in Fig. 4.

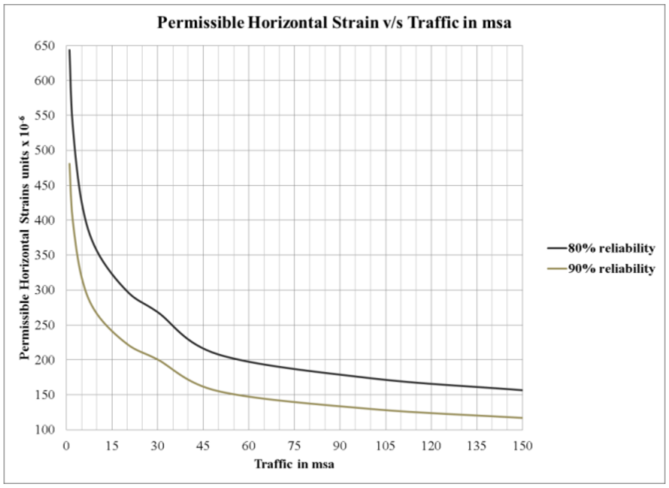

FIGURE 4(a) Permissible horizontal tensile strain values v/s traffic in msa

Horizontal tensile strain values are dependent on the modulus of bituminous layer. The viscosity gradient and the temperature variation affect the strain value. In Fig. 4(a) a small bend at 30msa is a result of the variation of viscosity gradient and temperature of the bituminous mix.

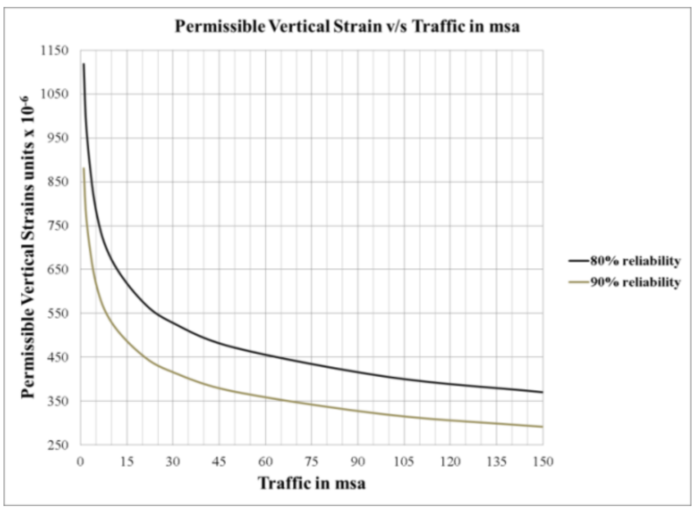

FIGURE 4(b) Permissible vertical subgrade strain values v/s traffic in msa

Based on Fig. 4(a) and 4(b) typical values for permissible strain limit are shown in Table 2.

TABLE 2 Limiting strains for conventional section

Description	Value
i. Horizontal tensile strain at the junction of the bituminous layer and granular base	297.97 x 10^{-6} micro-strain units
ii. Vertical subgrade strain at the junction of the granular sub-base and subgrade	577.73 x 10^{-6} micro-strain units

It was proposed by Strata Geosystems to design road section with a two layers of StrataWeb® Geocell SW356-150 infilled with granular sub-base (GSB) material above the subgrade.

Geocells were proposed within Granular Sub-base layer. Modulus of the portion of the layer within which geocells were placed was increased by a Modulus Improvement Factor (MIF). Computations are repeated with IRC recommended IITPAVE software with the appropriate moduli values. Varying the thicknesses by trial and error, the section of geocell reinforced pavement was arrived at as shown in Figure 5.

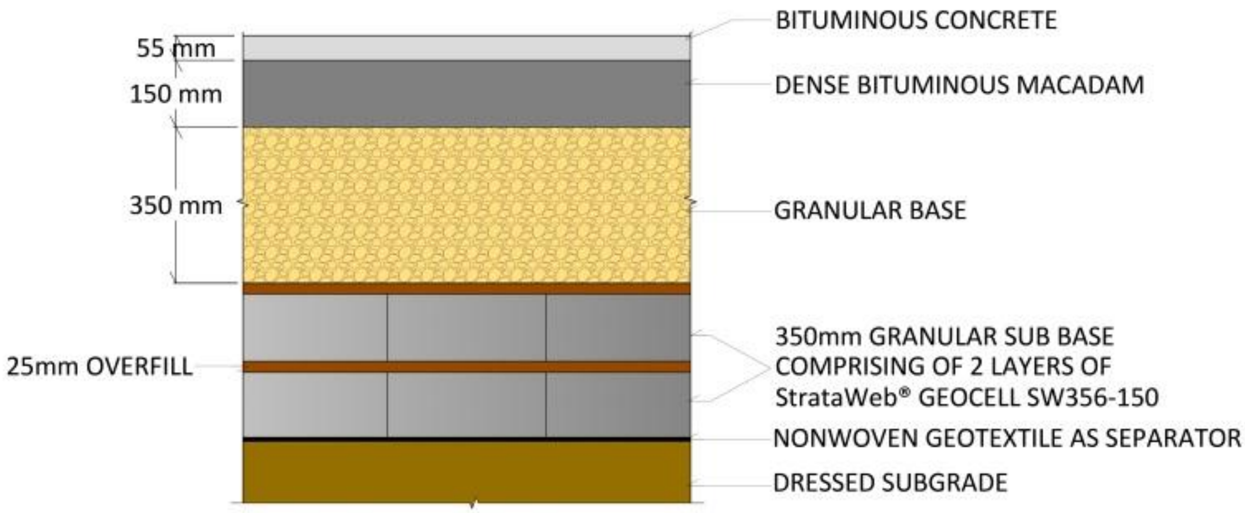

FIGURE 5 Geocell reinforced section (CBR – 0.5%, 20msa)

The geotextile layer below prevents inter-mingling of the in-filled GSB within the geocells and the clay of the subgrade. Material properties for analysis of a geocell reinforced section are shown in Table 3.

TABLE 3 Material properties for StrataWeb® geocell section

Layer Description	Elastic Modulus (MPa)	Poisson's Ratio (μ)	Layer Thickness (mm)
i. Bituminous Concrete (BC)	1700	0.4	25
ii. Dense Bituminous Macadam (DBM)	1700	0.4	50
iii. Granular Base (G. Base)	183.84	0.35	350
iv. Granular Sub-base (G.S.B) **SW356-150**	65.85	0.35	350
v. Subgrade	5	0.35	-

Computed strain values for the geocell reinforced section are shown in Table 4. The geotextile for separation, shown in Figure 4 below the GSB is not considered for computing strains.

TABLE 4 Computed strains for StrataWeb® section

Description	Value
i. Horizontal tensile strain at the junction of the bituminous layer and granular base	179.8×10^{-6} micro-strain units
ii. Vertical subgrade strain at the junction of the granular sub-base and subgrade	569.4×10^{-6} micro-strain units

DISCUSSION

The computed strain values for the geocell reinforced section are less than the limiting strain values for conventional section as shown in Table 5.

TABLE 5 Comparison of strain values for Conventional and StrataWeb® section

Description	Conventional section	Geocell section
i. Horizontal Tensile Strain	297.97×10^{-6}	179.8×10^{-6}
ii. Vertical subgrade strain	577.73×10^{-6}	569.4×10^{-6}

CONSTRUCTION

Owing to logistics problems owing to rains, the geosynthetic materials including the StrataWeb® geocells could reach the affected site only by the end of July 2016. However thereafter, rehabilitation work commenced immediately. Remnants of the existing road were scrapped off. The subgrade was dressed, levelled and compacted. A nonwoven was placed above the compacted surface to prevent intermingling of the engineered section with the weak plastic subgrade. Work was executed over half the width of the carriageway while allowing whatever traffic that can painfully move, to pass along the other side. Construction up to the GSB above the geocell took about two weeks for the completion. The construction sequence is shown in the Fig. 6.

FIGURE 6(a) Laying of Nonwoven geotextile on dressed subgrade

FIGURE 6(b) StrataWeb® geocells being infilled with graded aggregate

FIGURE 6(c) Granular base being compacted

FIGURE 6(d) Pavement without bituminous topping

The geocell solution by Strata allowed immediate movement of vehicular traffic. Amidst the heavy downpour in mid-August, the Authorities decided to assess the performance of the system under regular traffic and put-off asphalting the surface. The highway was opened to traffic for all class of vehicles directly over the granular base was laid. Figure 7 shows uninterrupted heavy traffic movement during heavy downpour. Subsequent to the mid-August downpour and opening up to regular traffic, no undulation or settlements were observed on the unpaved section.

FIGURE 7 Continuous traffic movements over geocells during monsoons

Thereafter, the surface was asphalted and work was deemed completed. The finished asphalted surface is shown in Fig. 8. Post construction visual observations were carried out. After one year, with conditions including the 2017 heavy monsoons, the condition of the same stretch (Figure 9) has proven the effectiveness of the geocell reinforced system.

FIGURE 8 Finished asphalted surface

FIGURE 9 Finished surface after one year

No distress in the pavement was observed indicating overall good performance of the road.

Assam PW (Buildings and NH) Department has candidly acknowledged the performance of road in one of its publications, stating "*The NH-44 at Churaibari once became infamous for mud and slash is now transforming into heaven of natural beauty. All this has been made possible by the use of geocell in road construction*."

CONCLUSIONS

1. Pavements with high traffic intensity and low CBR subgrade can be effectively designed with geocells.
2. Geocells enhance the life of pavement thereby reducing the maintenance cost. Riding quality of the highway also improves to a great extent.
3. While this case study addressed rehabilitation, geocells do reduce initial costs where the traffic intensities are high and the subgrade CBR is poor. Life cycle costs are invariably reduced.
4. With a leaner cross section, the pavement section can be laid faster. As this case study highlights, geocells are indispensable for providing quicker access during emergencies.

ACKNOWLEDGEMENT

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