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Behavior of geocell-reinforced granular base under repeated loading

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ABSTRACT

Major factors that influence the design of paved and unpaved roads are the strength and stiffness of the pavement layers. Among other factors, the strength of pavements depends on the thickness and quality of the aggregates used in the pavement base layer. The strength of pavement increases with increase in the thickness of the base which has a direct implication on construction cost whereas decreasing the thickness of the base makes it weak which results in low load bearing capacity especially for unpaved roads. Due to the lack of availability of aggregates, there is a need to identify alternative methods to minimize the thickness of the base without compromising on the strength of base. The use of geocell, a type of geosynthetics is a potential and reliable solution and studies are conducted in this direction. In the current study the performance of geocell reinforced base layer subjected to repeated loading is investigated. The results of the study are examined in terms of the resilient deformation and permanent deformation for different thicknesses of base layers under different repeated loading. The results showed that geocell reinforces the unbound aggregate thus reducing the deformation along with the reduction in the required thickness of the aggregate layer of unpaved roads. The amount of reduction of permanent deformation is found to be more for reinforced layer with higher thickness. The results also showed that the reinforced layers achieved maximum rut depth reduction compared to unreinforced section. The permanent deformation model modified for the geocell reinforced condition is calibrated using numerical analysis and the model can be used to predict the deformations for higher number of load cycles.

Introduction

In India and many other countries, there is a high demand for good aggregates and the availability of aggregate resources is limited. There is a need for development of sustainable construction methods which can handle aggregate requirements with least available resources and provide good performance. Hence it is imperative to strive for alternatives to achieve improved quality of pavements using supplementary potential materials and methods. Geosynthetic reinforcement is one of the established techniques of subgrade improvement and base reinforcement for over 40 years (Giroud and Han, 2004a,b). Geosynthetics have been successfully used to reduce permanent deformation, one of the main distresses in the paved and unpaved roads. In the case of unpaved roads, it is the granular base layer that has to bear the repeated application of wheel loads and thus has to be provided with greater depth. Granular materials of the unpaved structures normally showed significant plastic behavior, including stress-dependency behavior. In case of reinforced road sections, the traffic load from the axles is transmitted to the subgrade through the reinforced base

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course. Predominantly, the reinforced base course is assumed to be stiff enough to resist the deformation and transmit lesser stress to the subgrade causing it to deform. Properties of reinforcing geocell, base, subgrade materials, and the interaction of geocell with the soil contributing to the vertical and horizontal confinement characterize the overall behavior of the reinforced composite section. The inclusion of three dimensional geocell structure as soil reinforcement has been found to be effective in as it imparts additional confinement to the base material. Past researches (Jamnejad et al., 1986; Kazerani and Jamnejad, 1987; Chang et al., 2007, 2008; Thakur, 2012) showed that geocell reinforcement at the base course of an unpaved road improves the engineering behavior of the reinforced composite section, such as stiffness and bearing capacity. However, factors influencing the behavior of geocell-reinforced bases under dynamic loading are not well understood. In this study, an attempt is made to understand the various factors which influence the behavior of geocell reinforced granular base under repeated loading by conducting plate load tests. The implications of the current study are brought out in terms of improved pavement performance as the carbon emission reductions.

Literature review

The performance of the geocell reinforced base/subbase layers is studied in the laboratory by modeling the pavement sections in the form of box structures in which different pavement layers are laid and loading is applied in the form of static loading or repeated loading. To demonstrate the advantages gained from the use of geocell reinforcement in pavement construction, Jamnejad et al. (1986) conducted both monotonic and repeated plate loading tests. The tests showed an increase in stiffness and failure load with increase in infill density; improved elastic properties of the base layer; and improved cyclic response and retarded cyclic degradation by inclusion of geocell reinforcement. On a similar setup Kazerani and Jamnejad (1987) noted that geocell reinforcement could significantly improve the load-deformation and stress distributing characteristics of poorly graded materials and reduce the thickness requirement of the bases by 20–30%. Dash et al. (2001a) conducted similar laboratory-model tests to evaluate bearing capacity of a strip footing supported by a sand bed confined with geocell reinforcement. The test results showed improvement in the ultimate bearing capacity of the geocell-reinforced section by up to 8 times than that of the unreinforced section. This study also concluded that the geocell mattress could improve the performance at its width equal to the footing width. Dash et al. (2004) carried out laboratory model tests and demonstrated that geocell was the most advantageous soil reinforcement technique by redistributing the footing load over a wider area, resulting in reduced settlement compared to other planar and randomly distributed mesh elements.

Chang et al. (2007, 2008) investigated response of geocell-reinforced sandy soil under static and dynamic plate loading test. The study showed that the bearing capacity of sandy soil was improved by 40%. The study also concluded that for the same thickness of the base layer, the bearing capacity increases with increase in height of the geocell. Based on the experimental and numerical results, Han et al. (2008) showed a significant increase in the resilient modulus of the geocell-reinforced base over the unreinforced one. The influence of various parameters of reinforcements like height and width of the geocell were studied by Tafreshi et al. (2011). The study showed that the reinforcement's efficiency in reducing the footing settlement increased when the height and width of the geocell is increased. Thakur (2012) performed experimental investigations to study the Performance of geocell-reinforced recycled asphalt pavement (RAP) bases over weak subgrade under cyclic plate loading. The results of the study showed that the geocell improved the performance of RAP bases over weak subgrade as compared to that of unreinforced base section. The geocell significantly increased the resilient deformation of the RAP base and reduced the vertical stresses transferred to the subgrade by distributing the load over a wider area. The effect of providing more than one layer of geocell reinforcement on bearing capacity and settlement of footing was studied by Moghaddas Tafreshi et al. (2014). The study concluded that the efficiency of the reinforcement increases with the increase in number of layers by increasing the bearing capacity and reducing the settlement of the foundation. In his study, Dash (2012) explained the influence of the geocell material on the load-carrying mechanism of the geocell-reinforced sand foundations under strip loading. Geocells of different types were prepared using geogrids of different types. The test results indicate that the strength, stiffness, aperture opening size, and orientation of the rib of the geocell material influence the performance of the reinforced-sand foundation bed. All the above studies indicated that geocells are effective under repeated loading conditions. The two major distress experienced by flexible pavements are fatigue failure and rutting failure. The permanent deformation occurring in the pavement layers due to repeated loading contributes largely to the rutting failure. The design of flexible pavements need to address fatigue and rutting criteria which are associated with the evolution of resulting resilient and permanent deformation for different base thicknesses. The resilient deformation of the material is an important factor in determining the resilient modulus of the material. Thus the permanent and resilient deformation behavior of granular base with and without reinforcement, with variation in the depth of granular base will be a useful input in design of pavements and needs to be studied. The paper presents the results of experiments and analysis of the results to understand the behavior of geocell reinforced granular base during repeated loading. The experimental results are then validated with the two dimensional mechanistic empirical model for geocell reinforced unpaved roads for predicting the performance of pavements under large number of cycles.

Materials and test setup

Primarily, plate load test is carried out to study the deformations and other failure modes of materials when