BAMBOO-GEOTEXTILE BUOYANT SYSTEM FOR HEFTY CONSTRUCTION OVER DEEP SOFT SUBGRADE

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ABSTRACT

This Bamboo-Geotextile Grid-frame Buoyant System that is researched and developed at the university has to date being successfully commercialized and accepted and adopted reasonably well by the local construction industry. It is essentially an expedient, green and sustainable system of construction designed to solve a critical contemporary civil engineering problem of supporting very heavy construction safely over deep soft subgrade without attracting excessive settlements in due course. The method is founded on simple but established principles of creating a large but affordable surface area for efficient stress distribution which together with exceptional bending and buoyancy capabilities of bamboo culms would significantly reduce and attenuate original vertical applied stress on the soft bearing subgrade below. Consequently, it avoids stress concentration on soft subgrade and thus prevent failure of the supporting structures due to punching shear and excessive ground settlement in the weak bearing layer. As both the area and amount of buoyancy and thus the attenuation effect on the entire system can be increased by doubling or even tripling the same set-up within the system during construction readily, the extent of improvement to achieve too can be controlled at ease. This invention is truly green and sustainable that it overcomes not just an unresolved engineering problem but its large usage of bamboos will generate positive social impact by imparting considerable financial benefits to rural and indigenous population, an advantage rarely realizable in most major projects anywhere. The formal recognition of this system of construction came with its inclusion in "Guidelines for Construction on Peat and Organic Soils in Malaysia" issued jointly by the Ministry of Works of Malaysia and CIDB in October 2015. This has since witnessed more ready acceptance this method of construction by the construction fraternities from both public and private sectors in Malaysia. It is believed that the many successes recorded for this system prior to and after the issuance of the above Guidelines together with continuing experimental research cum theoretical development at the university will eventually allow this 'creation, design and product'('ciptaan, rekaan and buatan') of Malaysian origin will eventually opportune to venture beyond Malaysian soils.

Keywords: Bamboo-geotextile System, Heavy Construction, Deep Soft-subgrade, Settlements

Introduction

Increasing shortage of firm ground has compelled more and more heavy geotechnical structures like roads and buildings to be built over those once inappropriate very soft grounds where excessive settlement is often its grievous deterrent their adoption. To date, despite availability of a number of methods of construction over soft ground they nevertheless possess their individual identifiable practical limitations such as sophistication, costliness, time consumingness, inefficiency, endless post-construction settlements and costly repairs etc. The 'Bamboo- Geotextile Buoyant Platform System coined "Geobamtile" to be expounded here is a construction method devised to support heavy constructions over deep soft subsoil safely without substantial settlements in the soft subsoil and thus prevent bearing failure of soft subgrade and subsequently preserve overall stability of the heavy structure constructed.

THE 'GEOBAMTILE' SYSTEM AND ITS METHOD OF CONSTRUCTION

In practice, as shown in Figs.1 and 2, the Geobamtile system so designed is essentially a superbedly large 'raft foundation' formed inexpensively by tying together rounded matured bamboo culms each of 5 m length approximately by galvanized iron wires in a criss-cross manner to form into a grid network. The bamboo grid can either be fabricated in-situ at its designated location in the project as shown in Fig.3 or alternatively be prefabricated next to or in the close vicinity of the site where they are eventually to be laid as in Fig.4. Before the entire setup being overlaid by a layer of geotextile (see Fig. 5) which acts as a separator to prevent undesirable mixing of the soft soils below it and the good borrowed backfill materials brought in and compact to build the necessary embankment or platform for subsequent insfrastructure as in Fig. 6 or for building constructions as in Fig.7. In any case, perhaps worth mentioning that the construction of the 'geobamtile' system and thus subsequent construction upon it is carried out DIRECTLY on the existing soft ground with little, if any, site clearing and devoiding operations such as unsuitable material cutting, remove and cart away or any surcharging for consolidation etc. which are commonly carried out at the onset of most constructions on soft ground.

FUNCTIONAL PRINCIPLES AND DESIGN CONSIDERATIONS

The functional principles of the system are pivoted upon: 1)the bamboo grids and geotextile together will sustain and bear the vertical stress of superimposed load from above which is most critical at a location close to exiting ground surface by flexure as shown in Fig.9. The workdone by the applied stress and thus its energy is absorbed by the 'geobamtile' system and exhibited itself in the form of a sagging or catenary curve, a shape somewhat resembles a simply supported beam.

In addition, it should be pointed out that the extensive raft created by the 'geobamtile' over the entire loaded area would mean a good spread of applied stress over a large platform area created inexpensively and eventually lead to a more balanced distribution of a much reduced stress over the weak soft subgrade below (see Fig. 10(a)) and thus avoiding the emergence of any possible stress concentration which will lead to punching shear and/or bearing failure in the soft subgrade causing substantial differential settlements in the absence of 'geobamtile' system. Even more so, the buoyancy effect derived from light bamboos of the system would further reduce the vertical pressure that might apply to the soft subgrade below it as in Fig. 10 (b).

Fig. 1 – Cross Section of Bamboo-geotextile Grid Frame Raft Base

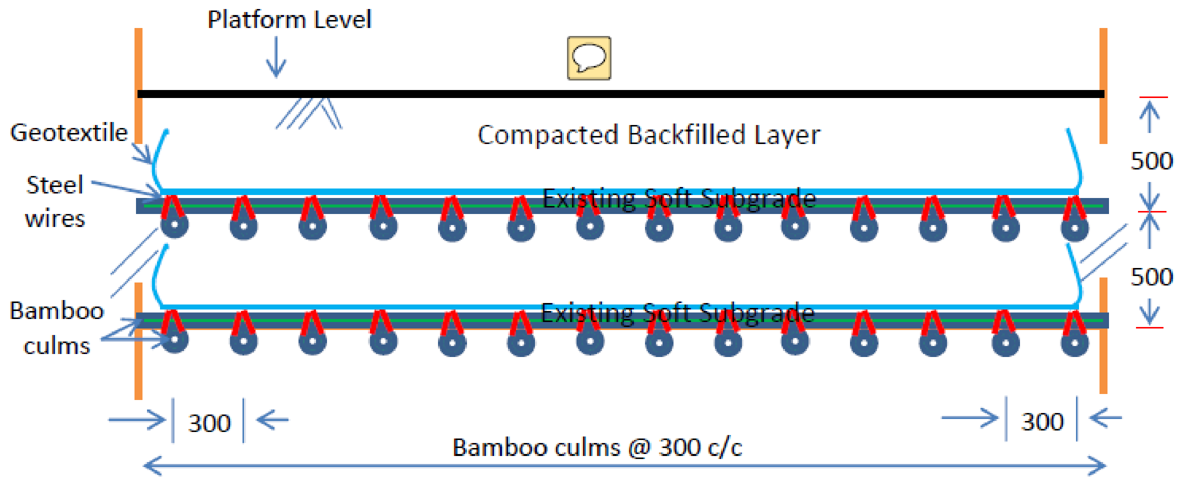


Fig. 2 – Plan View of Bamboo Grid Frame Raft Base without Geotextile Atop

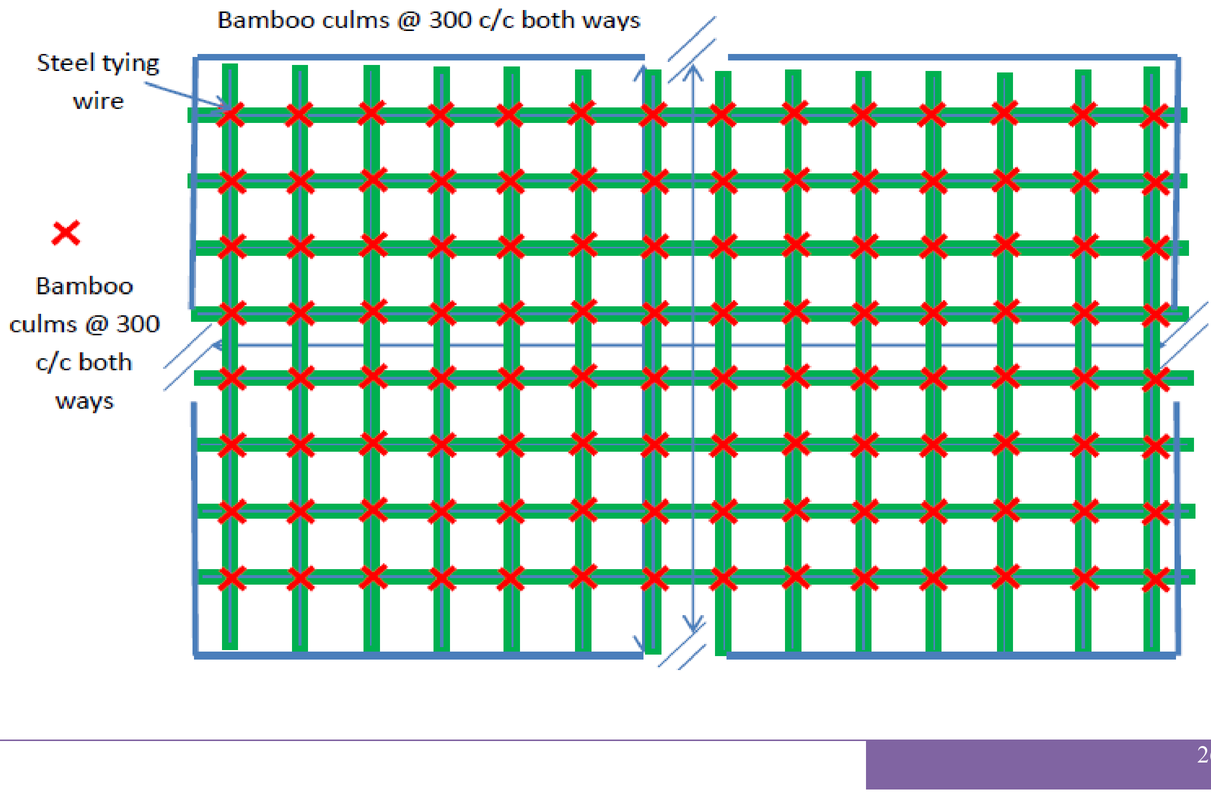


Fig. 3 – Bamboo grid frames being fabricated in-situ

Fig.4 – Bamboo grid frames are prefabricated next to the site ready to be transfer and laid

Fig.5 – Geotextile as separator being unrolled and laid atop of the bamboo grid frame so formed

Fig 6 – 'Geobamtile' system is deployed to support road embankment over soft peaty ground

Fig. 7 – The same system to support building platform for housing construction over soft peat

Fig.8 – Stress attenuation reapable through the deployment of 'geobamtile' system

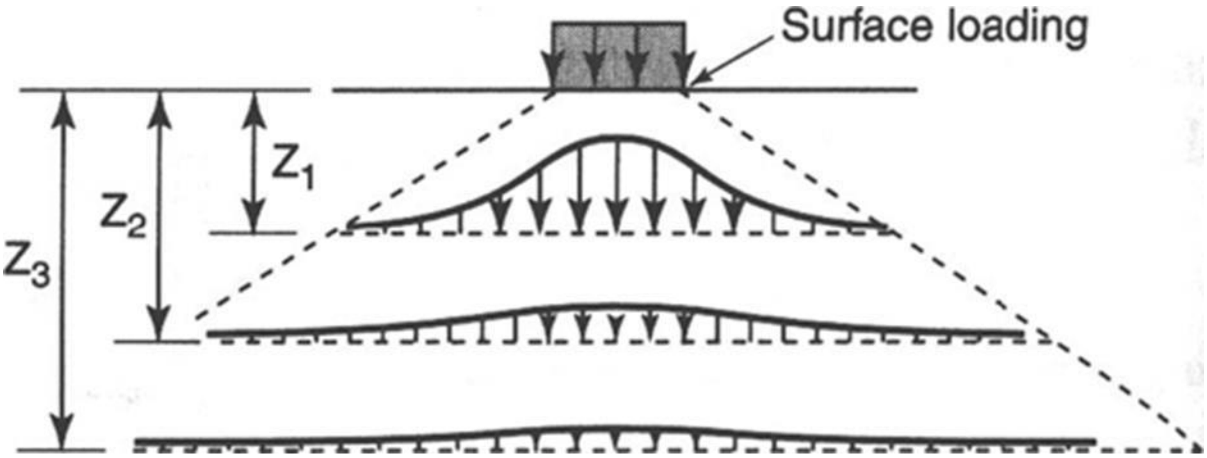


Fig.9 - The superimposed induced tress distribution below ground diagram and catenary shape of 'Geobamtile' in response that obtained during analysis and observed in practice

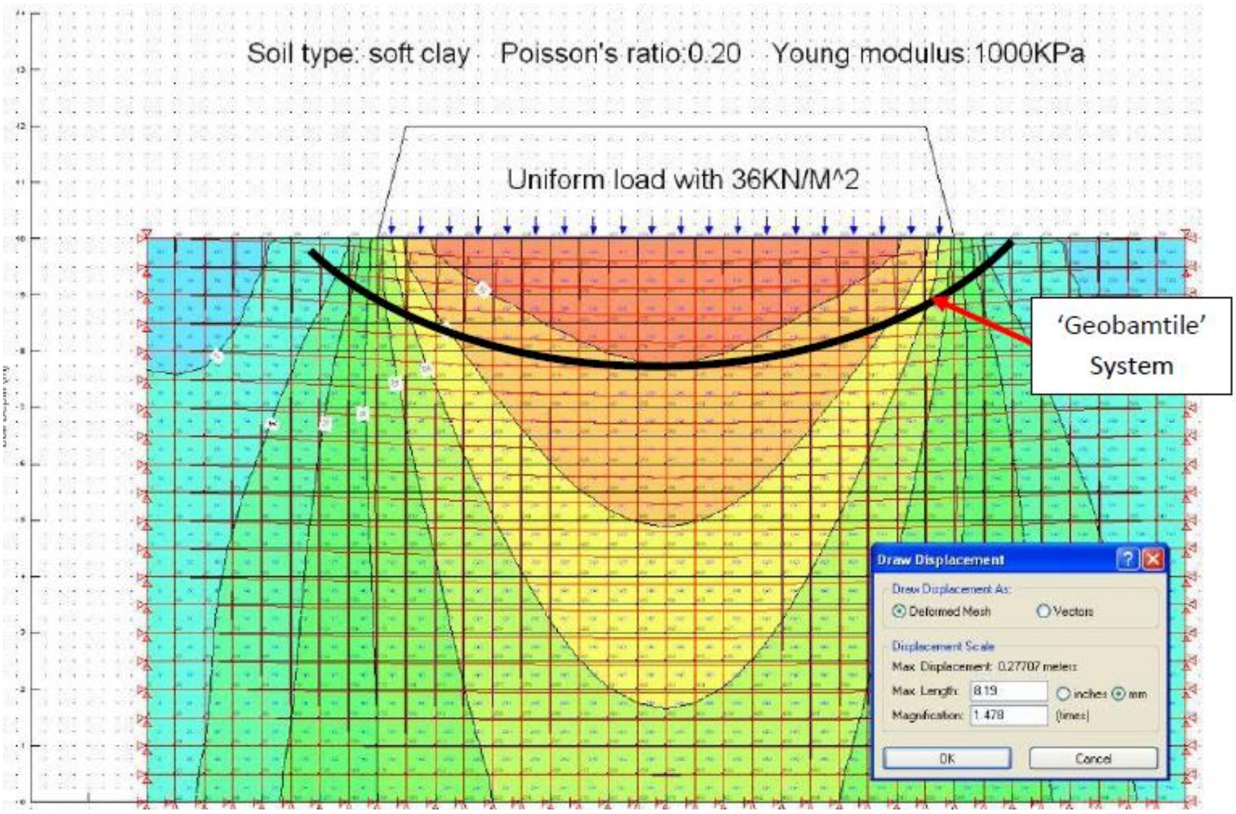
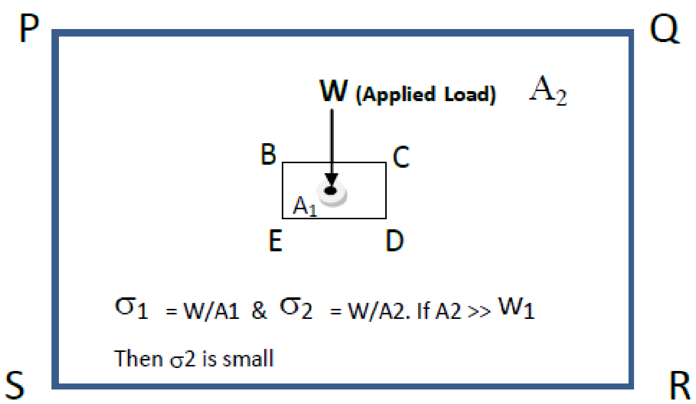
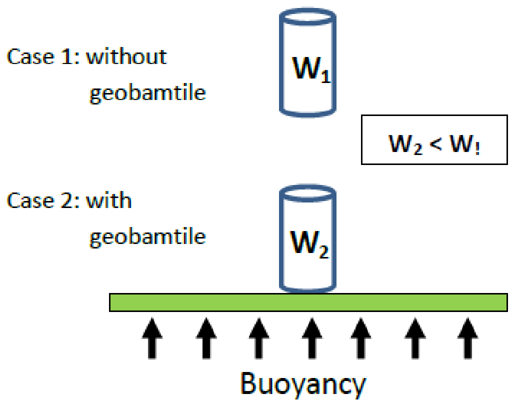


Fig. 10 – Stress Minimisation or Mitigation Contributors



(a) Enlargement of Area



(b) Buoyancy Effect

LABORATORY INVESTIGATION AND THEORETICAL ANALYSS

In order to put this subject matter on a more predictable basis and to come up with a rational method of design, intensive and relentless research efforts at university both at undergraduate and postgraduate levels are emphasized. So far, the problem has been approached from both structural and geotechnical engineering considerations. For the laboratory investigation, the behavior of the system devised is studied which include a)the deformatiuon characteristics of the bamboo- geotextile system both in the air and over soft clay, b)compare and contrast the longterm consoliodated settlements of an embankment with and without the support of the 'geobamtile' systems are illustrated effectiveness quantified. Structural theories related to both simply supported and continuously supported beams are also investigated where in the latter case apart from the two end supports, the beam is considered to be supported continuously by a series of weak soil springs which approximate the weak foundation soil. On geotechnical engineering aspect, Winkler model(Holsby et. al, 2004), improved Vlasov Pasternak's Model, Winkler-Pasternak-Kerr Foundations etc.(Pronk & Marion, 1998) and Hetenyi's method of Beam on Elastic Foundation (hetenyi, 1950) have all received serious attention. In addition, analysing the problem under both two-dimension (2-D) and three-dimension (3-D) environments using Finite Difference and Finite Element Methods are also conducted.

PROTOTYPE TEST AND FIELD TRIALS Being a committee member in drafting the

Admittedly, it is somewhat fortunate that many field trial opportunities involving prototype model of 'geobamtile' existed and successfully implemented and satisfactory results are recorded. Refer to Fig. 11 to 13 where some of projects which have successfully implemented and remained in most satisfactorily conditions after 20 years of completion. It is agaist this background that this method of construction has finally won the confidence of construction fraternities from both the public and private sectors alike in this country that it is finally adopted and included formally in a publication issued by the Ministry of Works and CIDB of Malaysia (Anon., 2015) for the use and benefit of construction in Malaysia typically, the Pan Borneo Highway in East Malaysia and the West Coast Highway in West Malaysia.

THE DURABILITY ISSUE OF BAMBOO IN SOFTGROUND

It is common to find that in all soft ground the water level is high or even saturated. Under such conditions microorganisms that cause decay can only proceed anaerobically under very low oxygen level condition and accordingly the rate of decay on any living species including bamboo would be exceptionally low. In this way the living plant like bamboo would seem to be 'preserved' and last over a much longer period than otherwise. The fact that Bakau Piles survive long period of time without showing sign of much decay under water but would rot comparatively fast above water where there is plenty supply of oxygen and microorganisms causing decay at a much faster rate via the aerobic process may well justify the explanation given earlier for longer life of bamboo can be expected when 'embedded' in soft inundated soils.

ADVANTAGES OF 'GEOBAMTILE'

Through years of experience that have been accumulated the following advantages of 'geobamtile' are realised. For easy comprehension, they can be summarized as follows:-

1) Construction-wise, the deployment of 'geobamtile' system can result in the avoidance of those problems commonly associated with construictions over soft subgrade as shown in Figs. 14 to 16 at different stages of the construction process, right from its onset, say, during clearing and preparation of site (see Fig. 14), then in the midst of construction (see Fig. 15), and after the completion and during the maintenance period (see Fig. 16).

2) The adoption of 'geobamtile' system for construction over soft ground has proven ALWAYS resulted in much shorter project gestation period and usually ahead of schedule when compared with other commonly used methods like piled-embankment, surcharge with vertical drains method, and lightweight polystyrene blocks etc. which are not only costly for their constructions but also involve long construction period that extention of time is common.

3) This method of construction involving mainly natural material like bamboo and thus it is undisputably a near 100% green and sustainable method of construction greatly sought after today.

4) Unlike implementation of many other major projects in this country or elsewhere where rural and indegeneous folks are merely on-lookers but the need of large quantity of bamboo for the 'geobamtile' method of construction means it creates a rewarding job for them as, say, bamboo resource harvesters. Thus, will in due course impart positive social impact to these communities in the country should this method of construction has become popular

Conclusion

This paper presents how a research and development (R&D) effort at a university can evolve eventually produce a satisfactory innovative method to facilitate the construction of heavy soil structures over very weak soft subgrade. Evidently, it is from various studies conducted and prototype and practical trials carried out including even full-scale or actual projects implemented before this method is formally justified and accepted from technical, environmental, economical, time and social aspects of considerations. In short, one of the main objectives of this paper is to illustrate how a prolonged critical contempory engineering problem to support heavy constructions safely over deep very soft subgrade can be resolved by R&D effort at a univiversity involving rudimentary fundamental theories and involves most affordable green and sustainable materials i.e. 'a few birds with one stone' solution eventually.

Following its formal recognition byrelevant authorities in the country, it is anticipated that this method of construction would from now look set to receive greater and more serious attention among construction fraternities from both public and private sectors alike. Besides, being an invention, creation, innovation and design of Malaysian origin, it is anticipated and have reasons to remain optimistic that this method of construction may inadvertently flourish and find itself a welcome beyond Malaysian soils.

Fig.11 – The adoption of 'geobamtile' system for rehabilitation of Interchange Ramp Project at Cyberjaya

Fig. 12 – The deployment of ‘geobamtile’ to stabilse very soft ground adjacent to the river for the construction of perimeter road of around the Wholesale Market at Batu Pahat, Johor.

Fig. 13 – Houses to be built over soft peat devoid of foundation but supported on ‘geobamtile’system

Fig. 14 – Prevent sinking of machineries and bogged-in of personnel at the on-set of the project

Fig. 15 – Avoid abrupt failure of contructed structure in the midst of the project

Fig. 16 – Significant drop and detachment of apron from the main body of the building

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