MACCELL™ 3D CELLULAR CONFINEMENT SYSTEM FOR IMPROVEMENT OF RUNWAY SUBGRADE IN BALESIN ISLAND, QUEZON, PHILIPPINES

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ABSTRACT

Import of engineered filling materials and weak runway subgradedeposits weretwo of the major concernsat the ongoing developmentsin Balesin Island, Quezon, Philippines. Albeit it is known for load support and ground improvement applications, 3D geosynthetic cellular confinement systems (geocells) have not been used widely in the Philippines due to itsbeing a new technology and thus unfamiliar to most consulting engineers. In here, the design concept of MacCell™ geocell for the subgrade improvement of Balesin Island's airport runway is discussed together with the existing site conditionsand the installation processes involved.With Maccaferri's 3D cellular confinement system (MacCell™), the shear resistance of infill materials is increased allowing the use of selected and qualified *in situ* materials to carry designed loads that would otherwise require imported resources for load support applications. MacCell™'s cellular structure also distributes concentrated loads to adjoining cells thus reducing the stress on the subgrade, increases subgrade modulus and consequently decreases the required total thickness of the runway base structure. Moreover, the potential use of MacCell™ geocell for runway construction is presented.

Keywords: MacCell, geocell, runwaysubgrade improvement, cellular confinement system, load support

INTRODUCTION

The Philippines is home to 7,107 islands, thusnowadays, island developments are one of the major investments being done by private companies to not only provide a getaway destination for tourists but also to showcase the country's yet-to-be explored natural beauty of pristine white sand beaches and tropical lush forests. To make the island a true tourists' destination, an efficient and readily available means of transportation is necessary.

Air transportation is considered as the most convenient access to and from an island, albeit construction of runways is often a challenge.

In general, islands like Balesin, Quezon, Philippines are composed of thick deposits of weathered soils on the upper soil strata, which are considerably weak to handle large stresses. As a result, ground improvements are introduced like soil stabilization by cement and import of engineered fill materials. However, these techniques require transport of heavy materials, which adds considerable cost to the total budget of the project. In this, geosynthetics,besides being lightweight in nature, have been proven to be economically competitive as theyoffer possible savings both in materials cost and in construction time, thus are considered a great option. When designed accordingly, geosynthetics not only deliver cost and time savings but can also provide equally or more reliable and sound engineering solutions in various civil engineering problems.

Maccaferri's three-dimensional (3D) cellular confinement system (MacCell™) is a type of geosynthetics known to be effective in load support applications when soft subgrade soils are encountered, or upper soil layers are unstable and good fill materials are locally unavailable and uneconomical, and/or if there are aesthetic or environmental considerations. MacCell™ geocell reinforces and improves weak soils by confining infill materials to carry designed loads. Aside from its use in slope stabilization measures, MacCell™ geocellis commonly applied for ground improvements of access roads and railways. As such, it has a great potential in the construction of runways over weak soil deposits, especially on isolated islands like Balesin. With MacCell™ geocell, selected and qualified *in situ* soils can be maximized for use.

In this particular project, Balesin Island - an

Fig. 1 The Balesin Island Club proposed developments showing the airport runway. *(Photo courtesy of Alphaland Corporation.)*

approximately 500-hectareproperty is being developed to be an exclusive private-leisure destination for members from Manila and Hong Kong. The island's runway was constructed over a reinforced and improved subgrade using MacCell™geocell. Details on the site conditions, design concept of runway, and installation of MacCell™ geocells are presented.

BALESIN ISLAND RUNWAY PROJECT

The Balesin Island Club's runway project was one of the first priority developments made in the private island. The runway spans to a length of 1,520m and a width of 30m (see Fig. 1). The runway features itself as part and parcel of the greenest runway in Asia being a massive water harvester whose side drains using high-density polyethylene-lined canals bring over 68,400 m^3 of rainwater to man-made ponds equipped with treatment facilities, and thus decreases significantly the amount of water needed for desalination or deep wells on an island setting.

Site Condition

Based from the conducted geotechnical investigation, the underlying soil at the location of the proposed runway is generally composed of layers of residual soils and/or previously laid fills of 5m-8m thick, underlain by thick formation of weathered sedimentary rock.

The overlying soil comprises predominantly of sandy deposits mixed with gravel, silt and clay of loose sub-layers occupying the depths shallower than 4.0m. Groundwater measurements based on borehole logs were found varying from 2.3m below the ground up to 15m in other areas.

In order to identify further the upper 2m soil strata, four test pits were established along the length of the proposed runway (refer to Fig. 2). From the excavated test pits, the geotechnical report recommended that the existing deposits in Test Pit No.1 (TP-1) and TP-2 can be used as subbase materials, whereas soils in areas of TP-3 and TP-4 shall be replaced by engineered fill materials. Also, base course of thickness greater than or equal to 100mm was recommended in areas of TP-1, TP-2 and TP-3, while 200mm-thick or more for area of TP-4.

Also, from the geotechnical investigation report, California Bearing Ratios (CBRs) of the soils from test pits and their corresponding maximum dry densities were determined and are presented in Table 1.

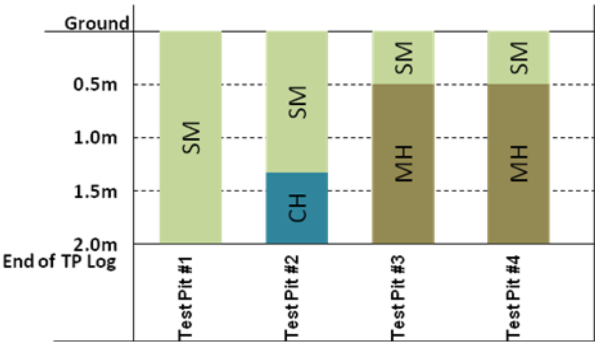


Fig. 2 Test pit logs at the immediate location of the runway with USCS soil classification (SM= silty sand, CH = Silty Clay, MH =Clayey Silt).

Subgrade Design Concept

The runway subgrade was initially designed to be composed of the following structure: (1) 300mm-thick concrete pavement, (2) 150mm-thick base course aggregates, and (3) 200mm-thick sub-base materials.

With the original design, engineered filling materials will have to be imported to the site. However, importation alone offered several disadvantages, both in time and in cost. Thus alternatives that can maximize the use of locally available materials were explored.

Table 1 CBR values and soil densities from test pits.

Test Pit No.	CBR Value (%)	Maximum Dry Density (kN/m^3)
1	23.70	16.92
2	34.80	17.16
3	13.40	16.83
4	4.0	12.89

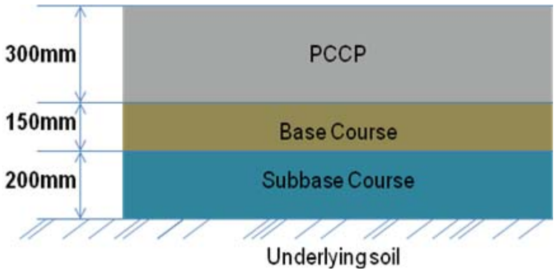


Fig. 3 Runway's original subgrade design

In this, a reinforced runway subgrade was recommended using MacCell™ 3D cellular confinement system. A free design software called FAARFIELD (Federal Aviation Administration's Rigid and Flexible Iterative Elastic Layered Design) was used in modeling the runway and subgrade elements and in designing the appropriate pavement thickness.

MacCell™ cellular containment system

As shown in Fig. 4, MacCell™geocell is a 3Dmattress consisting of perforated network of high-strength high-density polyethylene (HDPE) strips interconnected to each other to form a cellular structure used for load support and soil confinement applications. Lateral confinement, increased bearing capacity and tensioned membrane effect are the major reinforcement mechanisms of geosynthetics (Giroud and Han, 2004).

The 3D geocells are known to effectively provide lateral confinement to infill materials by combining the friction between the material and the geocell walls with the action of the reinforced base as a mattress to restrain subgrade soil from moving upward outside the loaded area and by vertical confinement to the infill material and the subgrade (Halahmi, I. *et al*., 2009).

Aircraft loads

Aircraft load equivalent to an ATR 72-500 model, a type of twin turboprop passenger and freighter aircraft, was considered. The load was modeled as Dual Wheel 60 load type in FAARFIELD. The said aircraft has been chosen to represent one of the common types of airplanes used for domestic travels in the Philippines.

Fig. 4 MacCell™ cellular containment system

Soil parameters

As an integral part in design procedures, CBR values and resilient moduli, M_R, were determined *a priori*to model the runway and underlying soil layers. Conservative equation for soil's resilient modulus was chosen from the comparison made between FAARFIELD's suggested equations (1&2) and AASHTO Design Guide formula (3).

$$M_R \text{ (psi)} = 26 \text{ x } k^{1.284} \tag{1}$$

where k = soil modulus in lb/in^3 and is expressed as,

$$k(pci) = \left(\frac{1500xCBR}{26}\right)^{0.7788} \tag{2}$$

$$M_R \text{ (psi)} = 2555 \text{ x } CBR^{0.64} \tag{3}$$

The behavior of CBR *vs* M_R is shown in Fig. 5. Based on the graph, in general, FAARFIELD equations result to relatively lower values for CBR less than 5% and AASHTO formula has proven to achieve a more conservative estimate of soil's resilient moduli for CBR ≥ 5%.

As shown in Table 1, the minimum value of CBR at site is 4% (Test Pit No.4). The equivalent value of soil's M_R obtained from FAARFIELD equationsis 5,999.32 psi (or 41.36 MPa). However, a lower value of 1,499.87 psi (or 10.34 MPa)equivalent to CBR=1% was adopted instead to consider possible existence of even weaker soils in the area.

From the soil investigation, the major soil constituent at the site is silty sand (SM). Although values of CBR from tests performed are relatively high for Test Pits 1 to 3, the major soil constituent was modeled with CBR=5% (M_R = 49.35 MPa) using equation 3.

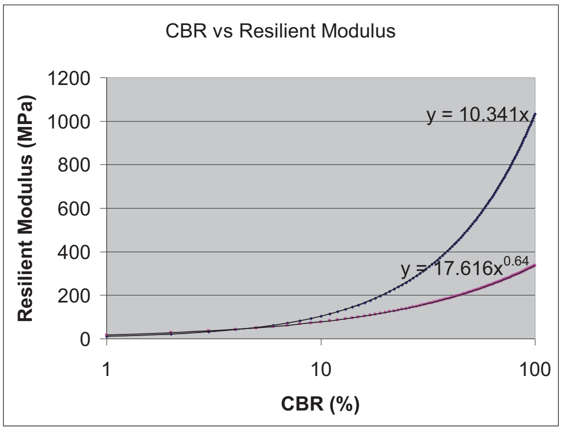


Fig. 5 CBR (log scale, %) *vs*soil's resilient modulus, M_R (MPa) for FAARFIELD modeling: (a) upper curve – FAARFIELD equations, (b) lower curve – AASHTO Design Guide formula. (Unit conversion *1 psi = 0.006895MPa*)

MacCell™ - reinforced subgrade

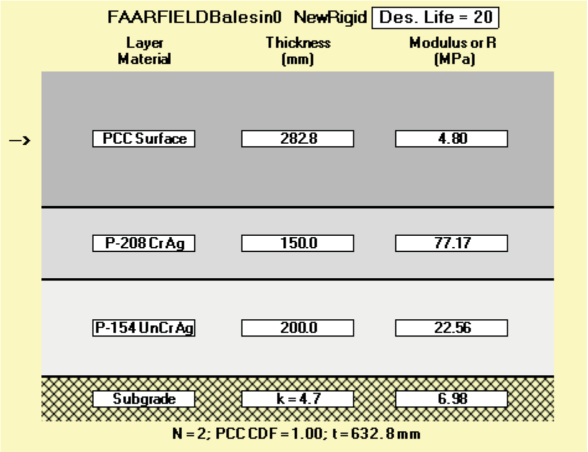
Two models were run in FAARFIELD: (1) original design of runway subgrade, and (2) MacCell™–reinforced runway subgrade.

The original design of runway subgrade was as previously shown in Fig. 3 with properties as depicted in Fig. 6. For the reinforced subgrade, a 100mm-thick MacCell™ was used over a properly compacted base. A 50.8mm-thick overfill was included in the model prior to the 300mm-thick concrete runway pavement layer. In modeling the effect of MacCell™ system, the *in situ*soil's resilient modulus was increased by a minimum value of 16.5% (Mengelt *et al.*, 2006; Halahmi, I. *et al.*, 2009).

The results of FAARFIELD analysis are shown in Figures 6 and 7 for the original runway subgrade and the reinforced runway subgrade, respectively.

Based on the results, the use of MacCell™ geocells for ground improvement of the runway subgrade with the *in situ* materials has resulted to an overall design runway pavement structure thickness of 440.3mm compared to the 632.8mm-thick structure when imported subgrade materials are used.

A 300mm-thick concrete pavement has been proposed and was eventually constructed for the island's runway.

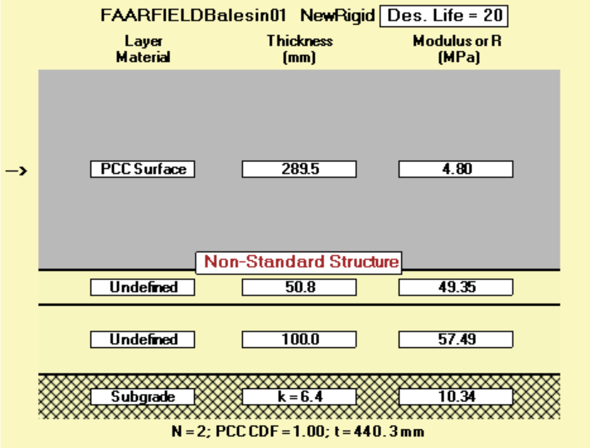


FAARFIELDBalesin0 NewRigid Des. Life = 20

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	282.8	4.80
P-208 CrAg	150.0	77.17
P-154 UnCrAg	200.0	22.56
Subgrade	k=4.7	6.98

N=2; PCC CDF=1.00; t=632.8mm

Fig. 6 Result of FAARFIELD design for original runway subgrade (Total thickness = 632.8mm)



FAARFIELDBalesin01 NewRigid Des. Life = 20

Layer Material	Thickness (mm)	Modulus or R (MPa)
PCC Surface	289.5	4.80
Undefined	50.8	49.35
Undefined	100.0	57.49
Subgrade	k=6.4	10.34

Non-Standard Structure

N=2; PCC CDF=1.00; t=440.3mm

Fig. 7 Result of FAARFIELD design for MacCell^{TM}-reinforced runway subgrade model (Total thickness = 440.3 mm)

MACCELL™ INSTALLATION

The general guidelines in the installation of the MacCell™ 3D cellular containment system are as follows:

1) The subgrade is prepared by compacting to minimum density requirement of 95%. Any unwanted materials are removed and depressions are backfilled to desired elevation. Refer to Fig. 8.

2) A geotextile is laid on the compacted surface. Overlap width is as prescribed by local governing standard. See Fig. 9.
3) As shown in Fig. 10, guide pins are then established to provide markings for the initial location of the MacCell™ geocells and to hold them in place prior to unfolding.
4) The sides and ends of MacCell™ geocell panels are connected using handheld stapling device, as depicted in Fig. 11.
5) Backfilling commences soon after enough panels of MacCell™geocells are installed. The *in situ* materials are backfilled on the geocells and overfilled them by 50.8mm (2inches) and are then compacted to minimum 95% density requirement. Refer to Fig. 12.
6) The preceding steps are repeated until the total area is covered by MacCell™ panels.
7) The compacted runway base is then surveyed prior to pouring of concrete.

Fig. 8 Compaction of existing platform at minimum 95% density requirement.

Fig. 9 Laying of geotextile at the prepared base prior to MacCell™ geocells.

Fig. 10 Installation of guide pins.

Fig. 11 Connecting ends or sides of MacCell™ panels with handheld equipment.

Fig. 12 Backfilling commences soon after enough panels of MacCell™ are laid.

An aerial view of the completed airport runway pavement in Balesin Island Club is shown in Fig. 13.

Fig. 13 Constructed runway with MacCell™-reinforced subgrade. *(Photo courtesy of Alphaland Corporation.)*

CONCLUSIONS

The case study of MacCell™ geocell-reinforced runway subgrade is presented. With the software FAARFIELD and the availability of geotechnical investigation report, *in situ* soils were explored for possible use as runway subgrade materials by introduction of MacCell™ geocell. Compaction of the infill materials played a key role in ensuring the load support mechanism and ground improvement feature of the system.

Moreover, MacCell™ geocell have been found to provide substantial capacity to carry aircraft loads of thinner overall pavement structure and have been proven its great potential as an economically-competitive engineered solution for construction of runways over weak subgrade.

ACKNOWLEDGEMENT

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