Application of high strength geogrid as load transfer platform to wharf structure for a container terminal

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ABSTRACT: Having recoded the 2nd highest growth rate in East Asia with GDP excess of 7% prompted the Vietnamese Government to support and initiate development of world class infrastructure especially in port sectors to support the continued economy growth. This was shown from the construction of US250 million Saigon Premier Container Terminal (SPCT), which is located along the western shore of the Soa Rap River within the Hiep Phuoc Industrial Park. Upon completion, this world class container terminal with state of the art technology which is located approximately 16km by road from Center of Ho Chi Minh City and in close proximity to its industrial hinterland will have the capacity to handle 1.5 million twenty foot equivalent units (TEUs) per year. This paper highlights the use of high strength woven geogrid for the construction of wharf at the terminal. The application of high strength woven geogrid is as load transfer platform with the main function as base reinforcement will be discussed in detail. The paper presents the main features of high strength woven geogrid, design of geogrid as load transfer platform on piled foundation and construction of geogrid over piled foundation. The construction method is very crucial especially method of joining the geogrid, alignment of geogrid to suit construction sequence and precautions measures taken to make sure that the piled foundation does not damage the geogrid.

1 INTRODUCTION

Wharf is a place where ships are harbored for loading and unloading activities. The wharf proposed for Saigon Premier Container Terminal (SPCT) comprises of fixed platform which will be constructed on pile.

As an alternative to common method of concrete platform above the piling, a more economical and simplify method using geogrid was introduce for this project. Since piles are expensive material, any reduction in the number of piles can offer significant savings on the total project cost.

Simple construction method and faster completion shortens the overall construction period of a project compared to conventional method of concrete slab. Formwork preparation, steel reinforcement installation and concreting works by skilled labors are replaced with mechanical installation of geogrid with a couple of well trained labors

2 GEOGRID SPECIFICATION

Geogrid is defined as *"a deformed or non deformed grid-like polymeric material used primarily for reinforcement with foundation soil, soil, rock earth, or any other geotechnical engineering related material as an integral part of a human-made project structure or system."*

Geogrid are mainly differentiated based on the type of polymer and the manufacturing process. The three most commonly used polymers to manufacture geogrid are *high density polyethylene* (HDPE), *polypropylene* (PP) and *polyester* (PET). For this project, where the application of geogrid is as load transfer platform, geogrid with the following characteristic was specified:

2.1 *Raw Material*

The geogrid shall be made from high molecular weight, high tenacity polyester multifilament yarns. Polyester products exhibit less creep than other polyolefin products. Creep behavior, i.e., extension of material under constantly applied load is very important factor in accessing long term load carrying capacity of polymeric materials. Creep rupture behavior of different polymeric materials at 23° C is shown in Figure 2. As can be seen from Figure below the HDPE and PP material has higher creep rupture rate as compared to polyester. Design guidelines given by various bodies thus specify much higher creep reduction factors for HDPE and PP geogrid as compared to polyester geogrid.

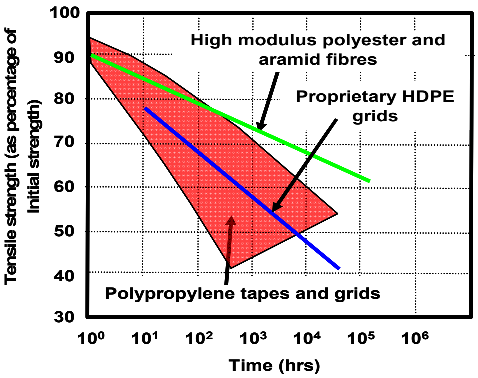


Figure 1. Creep ruptures behavior of different polymer material

2.2 *Polymeric Coating*

The polyester yarns must be protected by polymeric coating to prevent damage to the yarns during installation. This will increase survivability of the geogrid from installation stresses thus reduces the installation reduction factor.

2.3 *High Pullout Resistance*

The geogrid shall have rough surface to provide additional friction between geogrid and fill material thus increases the coefficient of interaction between the residual soil and the reinforcement. The aperture size of the geogrid shall be optimum to enhance the interlocking between the grid and the fill material.

2.4 *Stress Strain Characteristic*

Since the design is done based on Colin Method, the initial strain of the geogrid is assumed at 5%. The proposed geogrid shall have highest tensile strength at 5% strain. Polyester, HDPE and PP have their own stress strain characteristics. Short term stress strain characteristics of these materials are shown in Figure 1. As can be seen from Figure 1, polyester has better modulus than HDPE or PP.

2.5 *Flexible and Easy to Install*

The geogrid shall be flexible and can be easily installed on uneven surface. No pegging with nail shall be permitted on job site.

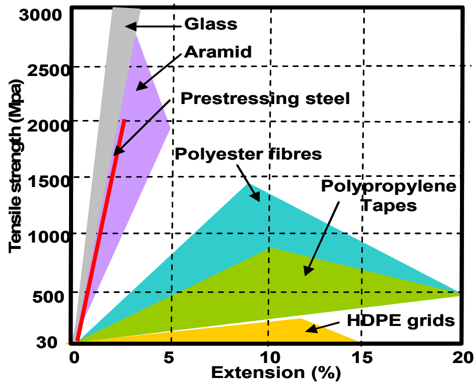


Figure 2. Short term stress strain characteristics of different material

2.6 *High Strength at Both Direction*

The geogrid shall be bidirectional; a geogrid which possesses similar tensile strength in both longitudinal and transversal direction.

2.7 *Quality Product*

All material supplied must be accompanied by a manufacturing certificate from the factory for quality control and quality management purposes. The material shall come from an ISO 9001:2000 certified factory. The geogrid acceptance shall be based on prove of quality certification from internationally recognized certification body such as ERA UK, BTTG and TRI.

2.8 *Design*

The material partial safety factors for the long term design strength of geogrid shall be derived according to BS8006: 1995 which is used as basis of design approach for stability analysis.

2 ADVANTAGE OF GEOGRID

High strength geogrid acts by transferring the loads from the soil arch between the piles into the adjacent piles. The availability of high strength geogrid up to 1200kN/m allows designers to increase the spacing between the piles and this reduces the total number of piles required in an embankment. Since piles are expensive material, any reduction in the number of piles can offer significant savings on the total project cost.

Simple construction method and faster completion shortens the overall construction period of a project compared to conventional method of concrete slab. Formwork preparation, steel reinforcement installation and concreting works by skilled labors are replaced with mechanical installation of geogrid with a couple of well trained labors.

3 DESIGN METHOD

The first step was to design the pile spacing based on the following requirements using foundation soil parameters in Table 1:

- The clear span between piles (s) is smaller than the thickness of the load transfer platform (hp).
- The ultimate bearing capacity of pile is larger than axial load of pile multiply by safety factor.
- The axial load of pile plus downdrag force shall be less than axial load of pile multiply by safety factor.
- The gradient of ground surface (G) is less than 1.33%.

Table 1 : Foundation soil parameters

Soil Type & Depth	Cohesion (kN/m^2)	Friction (Degree)	Unit weight (kN/m^3)
Selected sand (3m)		($\phi = 30^0$)	10
Very soft soil (18m)	20.2		5
Very soft clay (7m)	48		6
Very soft clay (8m)	75		7
Medium dense sand		($\phi = 30^0$)	10

Second step was to design the geogrid as load transfer platform. Three main stability checks was done for this project which is the lateral spreading, edge stability and the required tensile strength on the geogrid. BS 8006 and Collin Method of calculation were used as the basis of the design method.

3.1 Lateral Spreading

$$T_{1s} = K_a (\gamma H + q)H/2$$

where,
T_{1s} = required tensile strength to prevent lateral spreading
K_a = coefficient of active earth pressure
γ = unit weight of embankment fills soil
H = height of embankment fill
q = surcharge load

$$Le = T_{1s}/[0.5\gamma H(c_{iemb}\tan\phi_{emb})]$$

where,
L_e = minimum length of reinforcement
C_{iemb} = coefficient if interaction for sliding between geosynthetic reinforcement and embankment fill
$\tan\phi_{emb}$ = effective friction angle of embankment fill

3.2 Edge Stability

$$L_p = H(n-\tan\theta_p)$$

where,
n = side slope of the embankment
θ_p = angle between the outer edge of the outer most column and the crest of the embankment

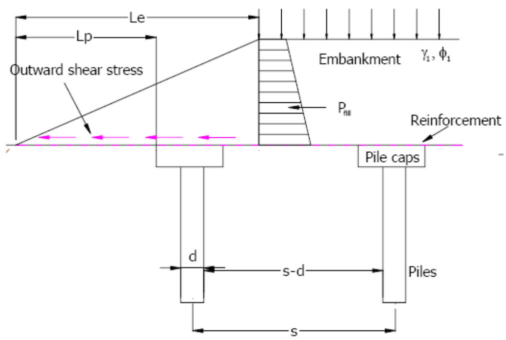


Figure 3. Lateral spreading layout

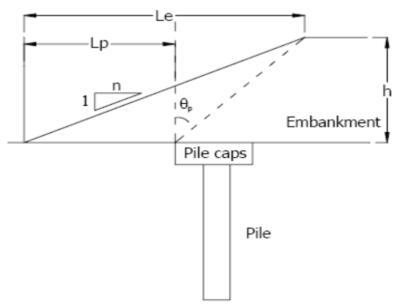


Figure 4. Edge stability layout

3.3 Tensile Strength in Reinforcement

$$W_{Tn} = [A_n + A_{n+1}]h_n\gamma/2A_n$$

where,
W_{Tn} = vertical load on the catenary layer of reinforcement
A = Area at reinforcement layer n or n + 1

$$T_{rpn} = W_{Tn}\Omega D/2$$

where,
T_{rpn} = Tension in beam reinforcement
Ω = dimensionless factor from tensioned membrane theory
D = design span for tension membrane

$$T_{rpn} = W_{Tn}\Omega D/2$$

Summary of Beam Reinforcement Calculation

Layer of Beam	A_n m^2	A_{n+1} m^2	D_B m	W_{Tn} kN/m	T_{rpn} kN/m
1	1.00	0.01	1.41	4.09	2.80
2	0.01	0.00	0.14	4.05	0.28

Design strength (60 yr) $\geq$ Maximum of $T_{1s,}$ T_{rpn}
$T_{d,60\ years} \geq 35.4$kN/m

Geogrid strength > 35.4 x Reduction Factor (1.82)
> 65kN/m

Maximum allowable strain at 65kN/m < 5%

Table 1. Physical properties of the proposed geogrid

Properties	Test Method	Min Value
Unit Weight	ASTM D5261	500 g/m2
Tensile Strength MD	ASTM D6637	100kN/m
Tensile Strength CD	ASTM D6637	100kN/m
Elongation	ASTM D6637	11%
Reduction Factor	Calculated	1.85
Aperture Size MD		21mm
Aperture Size CD		21mm
Long Term Design Strength (LTDS)		54kN/m

4 INSTALLATION METHOD

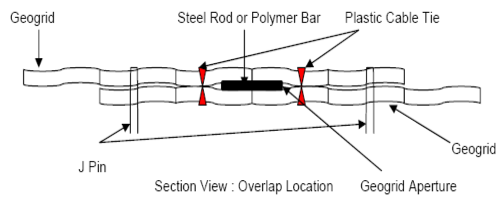
Step 1: Unsuitable soil was cleared from the site and the foundation soil excavated or filled and levelled to the designer's requirements. Sharp objects i.e. stumps, boulders or construction material that can puncture the geotextile are removed from the site.
Step 2: Piling work are carried out as per designer's specification. Recommended soil is filled up to the pile crest.
Step 3: Geogrid are manually unrolled. Care should be taken during unrolling to avoid wrinkles and to prevent damage to the geogrid.
Step 4: Adjacent geogrid panel are overlapped as per designer's requirement. Geogrid are positively joined by clamps

4.1 *Proposed Overlap Method*

The joins between the geogrid at the transverse direction to be done as following:

- Overlap the two geogrid to the recommended lap length as per FHWA HI-95-038 (Table 5-4) or as per designers requirement. In this case the proposed overlap was 1.0m.
- Allow galvanized steel bar polymeric or other joint bar woven through the aperture of the geogrid at the center of the overlap throughout the overlap width.
- Tie both layer of the geogrid with the bar with plastic cable ties at 1m c/c.
- Secure the overlap area to the ground using J Pin at 1m c/c at both sides of the overlap.
- Only one joint per length of geogrid shall be allowed.
- Joints in geogrid shall be pulled and held taut during backfill placement.
- The location of the joint must not be less than 2m from the slope surface

Step 5: The embankment shall be constructed as per



construction drawing

Figure 6. Cross section of geogrid overlap

5 CONCLUSION

This project was successfully executed using geogrid as load transfer platform and this method is being accepted and used widely around the world. The advance in geosynthetic technology has broadened the scope of application and has made construction of complex structures such as wharf on difficult location more simple and economical.

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