Assessment of Reinforcement for Reinforced Fill Structures and Slopes in Hong Kong

K. F. Man & P. L. R. Pang
Geotechnical Engineering Office, Kowloon, Hong Kong

ABSTRACT : Since the introduction in 1989 of an Endorsement Certificate System for the prior approval of proprietary products, intended for use in permanent reinforced fill structures in Hong Kong, three Endorsement Certificates have been issued. Some procedures for the administration of the Endorsement Certificate System are outlined in this paper. A number of factors are considered in the assessment of earth reinforcement in Hong Kong. Some of these factors are briefly discussed.

1 INTRODUCTION

The Geotechnical Engineering Office (GEO) (previously known as the Geotechnical Control Office) of the Hong Kong Government retains a record of all permanent reinforced fill structures and slopes in Hong Kong. Since the first reinforced fill structure (a retaining wall) was completed in 1981, a total of twenty four reinforced fill retaining walls/slopes have been completed up to 1993. A 6-tier steel reinforced fill retaining wall up to 40 m high, with a total surface area of 10 000 m^2, has recently been completed.

In 1989, an Endorsement Certificate System was introduced by the GEO for the prior approval of proprietary reinforced fill products. The operation of the Endorsement Certificate System is outlined in Geospec 2: Model Specification for Reinforced Fill Structures (GCO,1989), which also provides guidance on design and construction of reinforced fill structures with a near-vertical face. In 1993, GEO published a report entitled "A Partial Factor Method for Reinforced Fill Slope Design" (Wong,1993). This report provides guidance on design of reinforced fill slopes with an angle of face inclination exceeding 20° from the vertical. The Endorsement Certificate System has been extended to cover proprietary products for use in permanent reinforced fill slopes. This paper presents some administrative procedures and selected technical aspects related to the assessment of proprietary earth reinforcement under the Endorsement Certificate System.

2 ENDORSEMENT CERTIFICATE SYSTEM

The Endorsement Certificate System enables the GEO to carefully assess proprietary products intended to be used in permanent reinforced fill structures. Aspects which are examined in the assessment of endorsement submissions have been described by Man & Pang (1992). Upon satisfactory fulfilment of all requirements, an Endorsement Certificate, which consists of various documents including the manufacturer's specifications, the relevant national certificate and a technical schedule prepared by the GEO, will be issued by the Director of Civil Engineering of the Hong Kong Government.

Endorsement Certificates are reviewed annually. At the end of each year, the local agents of various endorsed products are required to provide information on the usage and performance of the products in that year. Inspections of completed reinforced fill structures are carried out by GEO staff regularly to identify any deficiencies in performance. On the basis of the available information, the Endorsement Certificate will either be renewed, amended or withdrawn.

Warning letters will be sent to the local agent if adverse reports have been received from designers/specifiers indicating that the products supplied have difficulties in achieving compliance with the requirements given in the Endorsement Certificate or that the structures have failed to meet the performance criteria specified. Withdrawal of the endorsement will be considered if no correct action is taken by the manufacturer/supplier after the issue of warning letters, or if problems persist.

3 ASPECTS OF ASSESSMENT OF EARTH REINFORCEMENT

3.1 General Considerations

A number of factors are considered in the assessment of earth reinforcement in Hong Kong. These include the environmental factors, viz. temperature and solar radiation, as well as the nature of locally available fill materials. Some of these factors are briefly discussed below.

3.2 Temperature

3.2.1 Local Data

Based on field temperature data, Howells & Pang (1989) suggested that in Hong Kong, the temperature at the soil/concrete interface of reinforced fill retaining walls incorporating concrete facing panels can be up to 35°C. For reinforced fill slopes, data on the distribution of temperature within the slope is not available. So far, reinforced fill slope design in Hong Kong has also adopted a design temperature of 35°C, i.e. the same as that used for concrete-faced retaining walls.

Most of the tests done by manufacturers to evaluate the performance of polymer reinforcement were carried out at around 20°C. Hence, additional testing is required to obtain data appropriate for the design temperature in Hong Kong.

3.2.2 Creep and Stress Rupture

For polymer reinforcement, creep tests and stress rupture tests are required for each product. These tests need to be carried out over a range of loads and temperatures (including 35°C and higher), and for a duration of over one year (>10 000 hours). Some of these tests are required to be carried out until the reinforcement ruptures. The object is to provide adequate data for the extrapolation of long-term allowable design load.

Most of the polyester geogrid manufacturers have only carried out creep and stress rupture tests on the constituent yarns, with very little data on actual products. The behaviour of geogrids is influenced not only by the constituent yarns, but also by the structure of the grids. Hence, an assessment of the influence of the grid structure is required.

In the absence of an internationally accepted standard, details of test methods used by various manufacturers for measuring creep and stress rupture are varied, e.g. sample width, gauge length, clamps, pre-loading, etc. Details of the test method adopted are required to be clearly described to facilitate assessment. Consideration is given as to whether the test method provides results representative of the behaviour of the reinforcement in the field.

3.2.3 Polyester Hydrolysis

Available research work on the degradation of polyester fibres due to hydrolysis was carried out on the naked fibres or on yarns. As a result, predictions of the strength reduction with time of polyester products are based on such tests. As to the sheathing (either of PVC or LDPE) on the polyester geogrids, no information on the degree of protection which it can provide against polyester hydrolysis is available. Nevertheless, the protective effect of the sheathing is beneficial and thus the predictions based on naked yarn results are considered conservative.

The available hydrolysis data give a wide range of results in the prediction of long-term loads obtained using various models for the extrapolation of high and low temperature test results. A partial factor of safety is required to be adopted to cover uncertainties in the evaluation of the effect of hydrolysis under Hong Kong design conditions (viz. 35°C, soil pH between 5 and 10, and a design life of 120 years) (Greenwood & Shen,1994).

3.3 Solar Radiation Intensity

Based on an investigation of the outdoor exposure performance of 14 geotextiles in Hong Kong, Brand & Pang (1991) found that deterioration of some geotextiles can be severe when subjected to prolonged outdoor exposure. For comparison, the solar radiation intensity in the United Kingdom is approximately 70 kLy (kiloLangley = 41.8 MJ/m^2) per year, whereas in Hong Kong it is about 120 kLy per year.

Endorsement submissions from manufacturers of polymer reinforcement usually contain performance data based on the products' exposure under temperate climate conditions. These data need to be examined in the light of Hong Kong conditions. Manufacturers are required to provide site handling procedures to guard against the effects of sunlight on the reinforcement prior to its installation and backfilling. If the polymer reinforcement is to be used in reinforced fill slopes where a wrap around construction is adopted, the period of exposure of the reinforcement on the slope surface could be up to six to eight months, prior to full establishment of vegetation. Special details (e.g. use of soil cover) may be required to protect the polymer reinforcement from ultra-violet attack.

3.4 Fill Materials

3.4.1 Grading Limits and Properties

Geospec 2 gives specifications for selected fill materials for the construction of reinforced fill structures and slopes. The Geospec requires that selected fill shall be either wholly "frictional" or wholly "cohesive frictional"; the respective grading limits are shown in Figure 1.

Manufacturers' shear strength tests on fill, as well as direct shear and pull-out tests to provide information on the coefficient of interaction, need to be assessed on their applicability to Hong Kong fill materials. The following are considered:

(a) whether the fill materials used in the tests comply with Geospec 2 specifications, and

(b) whether the testing and sample preparation procedures follow Geospec 2, in particular, Geospec 2 requires initial soaking of the test specimen under prescribed conditions.

3.4.2 Site Damage

While a good proportion of naturally occuring earth materials encountered in Hong Kong are suitable for use as selected fill, the properties of local crushed rock products (mainly granites and volcanic rocks) require attention. Table 1 gives the range of mechanical properties of some local crushed rocks (based on Irfan et al, 1991).

Crushed rocks of volcanic origin are usually very strong and contain sharp edges which may inflict damage on certain types of reinforcement. Site damage trials have been conducted by some manufacturers of polymer reinforcement using their own countries' fill materials. The results of such trials are assessed with due account taken of the nature of the materials used in the site damage tests. In deriving the factors of safety against site damage of the reinforcement, the effect of maximum particle size and angularity of the crushed rock need to be considered. Site damage trials using typical Hong Kong fill materials are considered useful for determining damage factors for some proprietary products.

3.5 Allowable Design Load

The long-term allowable design load of polymer reinforcement is derived from the characteristic tensile strength of the reinforcement divided by safety factors to account for uncertainties in the material (fm), installation damage (fd), and chemical and biological degradation (fc). Regarding the material factor (fm), Small &

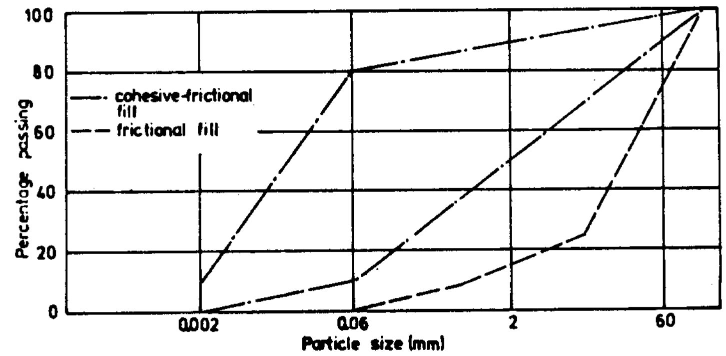

Figure 1 Grading Limits of Selected Fill Materials

Greenwood (1993) recommend the following contributory factors to be considered:

(a) scatter of stress rupture data and uncertainty in the method of extrapolation,

(b) possible change in rupture mechanism,

(c) synergy between load and damage effects,

(d) synergy between load and environmental effects,

(e) effect of temperature exceeding design temperature,

(f) possibility of material strength being less than its characteristic value, and

(g) dimensional effects of the product on strength.

Values of these contributory factors need to be assessed for individual earth reinforcement.

3.6 Hill Fire

Hill fires are not uncommon in Hong Kong, especially in the dry season. For structures with polymer reinforcement, the risk of fire damage has to be considered, particularly where crushed rock fill is proposed to be used with such reinforcement. This is because such fill material can permit the spreading of fire within

Table 1 Mechanical Properties of Some Hong Kong Crushed Rocks

Mechanical Properties	Volcanics	Granites
Aggregate Crushing Value (%)	10-18	21-29
Aggregate Impact Value (%)	9-13	15-31
Los Angeles Abrasion Value (%)	13-17	28-44
10% Fines Value (kN)	150-335	100-200
Polished Stone Value	58-64	50

the structure if the product itself can support combustion. Manufacturers are required to show that the construction details proposed for use with their products will not result in problems of instability should the structure or slope be subjected to fire attack. They are also required to provide details of suitable methods of repair for situations where part of the exposed reinforcement is damaged by fire.

4 CONCLUSION

The use of reinforced fill retaining walls and slopes is increasing in Hong Kong. A 6-tier steel reinforced fill retaining wall up to 40 m high has recently been completed. The adoption of polymer reinforcement for reinforced fill structures is relatively slow, due perhaps to the lack of experience and choice of endorsed polymer products. The assessment of five types of polymer reinforcement is currently in progress. It is hoped that with the availability of endorsed products, the beneficial use of the reinforced fill technique can be further facilitated.

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