Geosynthetics, J. Kuwano & J. Koseki (eds)

Application of soil nailing and reinforcement with geogrid in expansion and repair of mountain roads

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Keywords: geogrid, reinforced embankment, soil nailing, steep cut

ABSTRACT: The technique of soil nailing for cut slopes in combination with reinforced embankment with geogrid has recently been introduced to the widening or repair works of mountain roads in Thailand where space does not permit easy and economical design using the conventional cut and fill method. The successful use of the technique in the early application makes way for its increased use in the future. For an efficient and economical use, it is imperative that both the design and construction engineers be familiar with the principles of both methods and the materials used. This paper briefly outlines the theory, design, construction and supervision of the methods. References are made to experiences gained from two early applications in DOH projects. Recommendations are made for future improvement in the design and specifications, especially those of the reinforcing geogrid.

1 INTRODUCTION

The need to improve and develop road systems in the rugged mountainous areas in many parts of Thailand in recent years results in an increase in the amount of construction works to upgrade and widen existing narrow mountain roads. Repair works of damaged mountain roads slides brought about by heavy rainfall and runoff also increase enormously because of more new road construction and changes of land use and in the areas. In steep mountain areas, the conventional fill method may be not being economical and feasible because of constraints of space and large amounts of fill material in need. With the invention of technology of soil reinforcement, such repairs and expansions using fill embankment with steep side slope are feasible. The technique of combining soil nailing for road cut and geogrid reinforcement of embankment fill has been introduced for such application. It allows ease of construction and less disturbance of environment, and more importantly stable roads in the mountain environment. Soil nailing permits steep temporary cut into existing fill embankment so that the remaining road width can still be open for traffic during construction. Geogrid reinforcement allows the fill embankment to be constructed with steep side slopes.

The technique was recently introduced in Thailand by DOH. The first project involved the widening of a narrow stretch of the existing road to Phra That Doi Suthep in Chiangmai. The work was successfully completed in 2003. Subsequently, the technique is adopted for the repair of road slide sections of Highway 108 between Hod and Mae Sariang in Mae Hongson. The works are under construction. It is expected that the technique will become increasingly used in the future. Thus the author feels that for efficient and proper application, it is imperative that the highway engineers, both designers and construction supervisors, be familiar with the theory and principle behind the technique and the materials used, especially geogrids which may be obtained from various sources. In additional the design and construction method can be fine-tuned using the observations and experiences gained from these early works made in the country.

2 SOIL NAILING

The first soil nailed wall was built in France in 1972. The first application in Thailand was at a site of a beach resort hotel in Kamala bay in Phuket in early 1990s. The method is to permit soil excavation with steep or vertical slope face. Throughout the years the technique has been applied in construction works worldwide. Good references on design applications have been made available (e.g. ENPC, 1991).

3 REINFORCED EMBANKMENT

The technique of embankment reinforcing with inclusion of horizontal layers of tension elements has been widely utilized worldwide as an effective method to construct steep walls or embankment slopes for variety of civil engineering applications. The technique was firstly developed in France using steel strap reinforcements which has been patented under the name of Reinforced Earth Wall. Following the rapid development and advancement in geosynthetic materials, geogrids are used in place of the steel strap reinforcements. Although the geogrids may deform at a much larger elongation than the steel reinforcement under load, their function as soil reinforcement is normally satisfactory as deformation of the structures can be kept within the tolerable limits.

In principle, soils inherently have low tensile strength but a high compressive strength. Tensile elements may be incorporated to increase forces resisting failure, thereby improving stability of the structures. Tensile elements may also be incorporated to reduce shear strains in soil, thereby reducing deformations. Reinforced soil is a composite material of soil and tensile elements. The interaction of the soil and tensile elements under load is rather complex. In a reinforced soil slope, mechanisms governing the force resisting failure may be summarized as follows:

– soil behaviour : soil-soil shearing
– reinforcement behaviour: tensile rupture of reinforcement
– composite behaviour: reinforcement pullout from soil, shear between reinforcement and soil; and shear between reinforcement and facing.

3.1 *Design approach*

To conform with the international design standard (Eurocode), the global safety factor is replaced by partial safety factors (resistance factors and load factors) in the design analysis. The design calculation procedures and examples can be found in the BS 8006: 1995 and the guideline documents available from some well known manufacturers of geogrids, e.g. Ten Cate Nicolon (1998). The calculation method has been presented in numerous seminars or workshops held in Thailand, some of which were organized by ACSIG of Asian Institute of Technology.

3.2 *Choice of geogrid and specifications*

Nowadays there are numerous brands of geogrid and geotextile available in the market, thus selection and issuing specifications on the materials can sometimes be problematic, both technically and contractually. Most of these brands have good track records. Therefore for use in Thailand, any of them may be used to satisfactorily construct reinforced earth structures to the engineering requirements on safety and serviceability of the structures even though they may have slightly different chemical compositions and values of strength and strain.

The geogrids are mainly made from high molecular weight and high tenacity polyester materials (polyethelene, PET or HDPE/polypropylene, PP) with add-on treatments to make them mechanically and chemically durable for geotechnical applications. In principle the engineers should concentrate on the required mechanical and durability properties of the geogrid rather than their chemical compositions and manufacturing process in evaluating the quality. The advance in material science in manufacturing geosynthetic materials has gone so far that engineers should not be too concerned about the chemical composition of the material in making specifications.

The standard tests are available to prove the needed mechanical quality of the proposed brand of geogrid. From economical point of view, the designer should use the mechanical property values (tensile strengths and strains) that encompass the range of property values of acceptable brands of geogrid available in the market. It is not sensible to design the structure with reference only to one brand of the material and issue technical specifications along that line. The specifications may state a conforming brand of geogrid to the requirements, but a provision must be made for accepting alternative brands of the conforming quality.

4 EXPERIENCES IN DOH PROJECTS

The technique of reinforced embankment or wall with geogrids has become commonly adopted in highway construction in Thailand. However, the use in combination with soil nailing in mountain road construction was only recent.

The experiences obtained from the projects are outlined below.

4.1 *Hwy 1004 (Doi Suthep)*

It was the first project adopting this technique. A narrow stretch of the mountain roadway between Km. 14+000 and Km. 14+275, just before Wat Phra That Doi Suthep, was to be widened. The existing steep side slopes required that the added fill embankment must be made using geogrid reinforcement. This heavy-traffic road section needed to keep open while the construction works were carried out. Thus soil nailing was adopted for the steep excavation of the existing road way to seat the new reinforced soil embankment. In the contract, a preliminary design was outlined which included the typical section of the cut and fill. The maximum depth of the cut and fill along with typical dimensions soil nailing and geogrid reinforcement (length and spacing) and drainage system were given. However, the contract required that the contractor conducted detailed topographic survey of the site area and soil borings after the start of the contract so that the detailed design by the contractor could be precisely made in accordance with the actual subsoil conditions.

The typical section in the detailed design is as shown in Fig. 1. The cut depths were generally shallower than those of the preliminary design (4-8 m versus 4-12 m) largely due to shallower bed rocks. Because quantity and dimension of the nails were specified in the preliminary design and considered as the condition in the contract, it was not possible for change in the detailed design to reflect the actual soil condition. This was one of the drawback in the conditions of the contract.

However, it was not the case for geogrid reinforcement. The contract conditions and specifications on the geogrid were reasonably made to allow for optimum design and flexible choice of the geogrid material. The contract did not specify in details the size and strength/strain values of the geogrid. As per the required mechanical properties, it only specified overall factor of safety on the tensile strength in design calculation (F.S. = 2.50).

The road widening work was successfully completed using the technique even though it was slightly delayed beyond the contract period. The method was efficient for such a tight space construction. It was observed the use of concrete pads as facing element of the nailed slope was not suitable due to problems of soil erosion and caving behind the pads. Conditions of works during construction of the works are shown in Fig. 2.

4.2 *Hwy 108 (Hod-Mae Sariang)*

The technique is being adopted for repair of the major slide of side slope of the roadway at two locations at Km. 86+000 to 87+000 (Fig. 3). The slides caused by heavy rainfalls and runoffs brought down almost

Figure 2. Works during the construction-Doi Suthep Road.

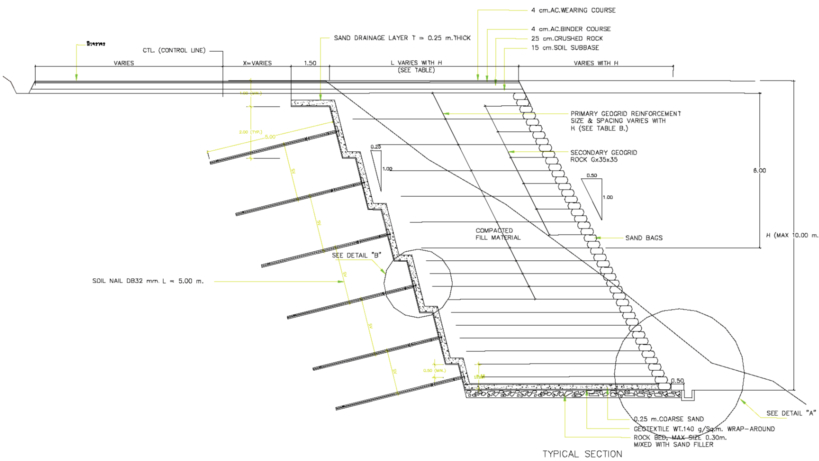

Figure 1. Typical final design of Doi Suthep Road.

Figure 3. Failure of road at Km. 86+300 Hwy. 108.

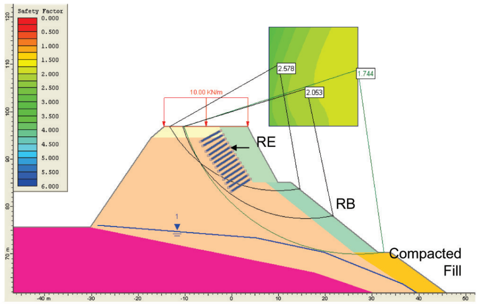

Figure 4. Stability analysis by SLIDE software.

a half width of the road pavement at the top of the high fill in this steep hilly area. The contract conditions and the preliminary design of the soil nailed cut slope-reinforced fill embankment of the two sections were essentially similar to that specified in the early project. However, the preliminary design specified use of geogrid reinforced fill on the slope faces in most parts of the high slope areas (50-60 m high) which did not seem necessary.

The slope face inclined at gradient gentler than 1:1.5 (V:H). In addition, the specifications on the geogrid materials specified in details the chemical compositions and values of mechanical properties as per one brand of geogrid. This contract conditions make it difficult for the details design to come up with an optimum design and economical selection of geogrid to reduce the project cost while maintaining safety and function of the built structures. Figure 4 shows result of the stability analysis.

5 CONCLUSIONS

- Experiences gained from application of soil nailing and geogrid reinforced fill in widening of mountain road and repairing of slope slides in the country suggest that it is an efficient and safe technique for work in limited space.
- However, there are needs to make the contract conditions more flexible to permit changes to optimize, economically and safely, the detailed design made during the course of contract.
- In view of many available makes of geogrid, there are needs to standardize specifications so that the contract may allow fair competition in the choice of the material.
- A brief outline is given in the paper on the fundamental and design of the soil nailed cuts and geogrid reinforced embankments.

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