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Application of geosynthetics to road in loess area in northwest China

Tao L., Zhang Y. & Wu W.
College of Civil Engineering, Beijing University of Technology, China

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ABSTRACT: Loess, with high permeability, collapsibility, slaking, is uniform in grain and high in porosity and low in moisture content. It is very easy to collapse when subjecting to water and loading. In China, loess distributes about 640,000 km^2, almost covering most of the northwest China. Zonal highway stretches most loess terrain in western China. Due to its special properties sensitive to water, geohazards, such as soil erosion, slope instability, debris flow etc frequently occur in the loess area in the condition of heavy rainfall, which results in tremendous loss and damage to road. Based on extensive field investigation, types and causes of highway hazards in loess are presented. The most effective way is to prevent water/rainfall from infiltration into roadbeds and embankment slope. In terms of road hazards, principles of application of geosynthetics in loess highway are suggested. In the paper geosynthetics application in preventing roadbeds, pavement, embankment slope and drainage from damage and failure are discussed in details with emphasis on special hazards in loess.

1 INTRODUCTION

Loess, with high permeability, collapsibility, slaking, is uniform in grain and high in porosity and low in moisture content. It is very easy to collapse when subjecting to water and loading. In China, loess distributes about 640,000 km^2, almost covering most of the northwest China. Zonal highway stretches most loess terrain in western China. Due to its special properties sensitive to water, geohazards, such as soil erosion, slope instability, debris flow etc frequently occur in the loess area in the condition of heavy rainfall, which results in tremendous loss and damage to road. With the development of western areas, these problems are becoming even more serious.

With the varying landforms and steep slopes, cut and backfill is necessary to construct a highway in the area with high cut slope and backfilled embankment. Moreover due to the special property of loess and climate, loess is apt to intensive corrosion, which in turn causes roadbed, embankment, and pavement to fail or damage. Uneven settlement of roadbed, pavement sinking or cracking is very common hazards to road there and seriously affects road safety and service.

It is well known that geosynthetics is one of the most effective ways in protecting roads from hazards and now widely used in highway construction. However it is seldom used in loess area.

A comprehensive research was conducted by the authors in northwestern China for more than three years on application of geosynthetics in road in loess. Based on extensive field investigation, types and causes of highway hazards in loess are presented. The most effective way is to prevent water/rainfall from infiltration into roadbeds and embankment slope. In terms of road hazards, principles of application of geosynthetics in loess highway are suggested. In the paper geosynthetics application in preventing roadbeds, pavement, embankment slope and drainage from damage and failure are discussed in details with emphasis on special hazards in loess. Geonet and geocell with plants growing on them are used together to prevent the embankment slope from erosion and to keep the slope stable.

The above-mentioned techniques are used in several trial roads. Performance of reinforced embankment, pavement and drainage were carefully examined with detailed instrumentation to better understand the mechanism and optimize parameter for design. After three years test and study, good results are obtained and hazards to road drop remarkably. The relevant techniques have great potential for highway construction in loess area.

2 HAZARDS AND REASONS OF ROAD DAMAGE IN LOESS AREA

Based on extensive field investigation, it is found that the special features of loess cause damage of road, among which the collapse deformation of loess is the key reason. Infiltration of water from rainfall makes the collapse deformation worse and intense. It is summarized that four main failure types are as follows:

2.1 Due to roadbed cavity, insufficient strength and excessive settlement, the road suffers of serious cracks, wheel rut and unacceptable surface deformation. Figure 1 shows the long longitudinal cracks found on Line S202 in Ningxia Province.

Figure 1. Longitudinal crack on pavement.

2.2 Due to improper design and construction or poor maintenance, roadbed may be eroded by infiltrated water and cause cavity inside of roadbed. Cavity occurrence, over deformed roadbed or even big cracks can destroy roadbed structure as shown in Figure 2.

Figure 2. Roadbed cavity on Line Xiji-Haiyuan Highway.

2.3 Intensive erosion, scouring and poor drainage system may cause failure, instability to embankment and cut slope.

2.4 Intensive erosion of rain cause the slope soil to collapse and in turn make the slope and bridge protection to fail. Culvert cracks due to its foundation over sunk.

Figure 3. Slope erosion disables the slope protection.

To sum up, collapse deformation is the main reason causing road failure in loess. However water from rainfall and ground plays a key role in loess collapse deformation. It is therefore easy to understand that adequate drainage and water proof method can be very effective to reduce road hazard in loess. The following work also focus on water control and soil reinforcement with geosynthetics.

3 HAZARD PREVENTION OF ROADBED WITH GEOSYNTHETICS

At the trial road geogrid is used in road embankment to reinforce the backfilled soil. Composite geomembrane is put on the drainage slot to protect the soil below/near the drainage from water infiltration. The typical layout of the embankment design is shown in Figure 4.

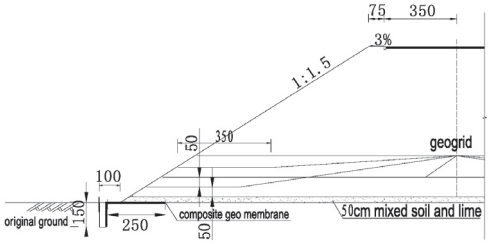

Figure 4. Reinforcement and infiltration protection of embankment.

Detailed instrumentation including deformation, settlement and earth pressure are made to evaluate the design and protection. Numerical modeling of FLAC is also use to understand the mechanism of the system. After more than two years, the trial road experienced heavy rains and heavy trucks with only several centimeters settlement. No cracks and obvious deformation is found.

4 PAVEMENT REINFORCEMENT

In order to check the validation of reinforcement to pavement, test was conducted using a beam with and without fiberglass geogrid in bituminous concrete in laboratory. The beam was tested subjected to loading, low temperature and fatigue, which proves that bituminous concrete with fiberglass geogrid has much higher performance in durability, strength. The fiberglass geogrid was used in trial road with layout as shown in Figure 5. After 3 years no crack, wheel rut and obvious deformation is spot so far. The technique is now widely used in highway surface construction in northwestern provinces.

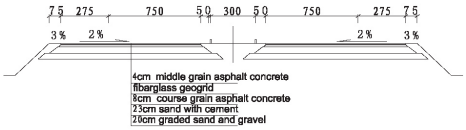

Figure 5. Fiberglass geogrid put between asphalt concrete.

5 EMBANKMENT SLOPE PROTECTION WITH GEOSYNTHETICS

Geocell and geonet are used on the embankment slope. Fertile soil is put into the geocell and glass seed is planted in the soil. The geocell can hold the soil and seed in relative steep slope. The geonet is then put on the top of geocell to prevent the soil and seed from erosion of heavy rain. The method is very effective for loess embankment slope. The protection of slope can stop rain erosion to the surface of slope, retain the stability of slope and be environmental friendly, as shown in Figure 6.

Figure 6. Comprehensive protection of embankment slope.

Field Investigation shows that water proof is the key to protect the road drainage system in loess area. Most failure occurs at the entrance and exit with respect to that water infiltration into the loess results in loess collapse deformation and drainage slot or culvert failure. It is therefore to emphasize the protection of the sensitive parts. Geomembrane is put on top of culvert and slot foundation. Soil 0.5 m thick mixed with 30% lime is laid between foundation and culvert and slot. After 3 years and compared with those drainage system without special treatment, the results are quite encouraging. The treatment is also widely used in loess with high collapse loess.

6 CONCLUSIONS

Geosynthetics is widely used in road in northwestern province now. The effectiveness and validation are proved to control road hazard in loess area, reduce maintenance and prolong service durability and improve road performance and safety. Based on 3 years study and investigation in field, the following conclusions may be drawn.

(1) It is the special feature of loess, that is collapse deformation after saturation, that cause a series of hazards to road. Prevention of water infiltration is the key to control the hazards.
(2) Geogrid reinforced high embankment can increase the overall strength and stability of embankment, reduce settlement. Drainage system protection using geomembrane can effectively control infiltration of water into embankment and foundation of slot and culvert.
(3) Fiberglass geogrid is both effective and economical in preventing wheel rut and reflecting cracks. Compared with other material and method, spreading fiberglass geogrid just below pavement is more effective.
(4) Combination of geonet and geocell with grass or other plants is both effective and environmental friendly to embankment slope. It can reduce slope erosion and rain filtration, enhance slope stability.

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