Successful mitigations of riverbank slope stabilizations and road failures caused by excessive rainfalls due to climate change at national road 1B (NR 1B) in laos PDR

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ABSTRACT

The sites of the successful road embankment and pavement repairs were located in Laos PDR at National Road 1B (NR 1B). National Road (NR) 1B connects Laos to China. Illustrations of the road embankment and pavement failures and their successful mitigations are discussed. The mitigations of the first case (Case 1) consist of PEC-150 geotextile reinforcements with gabions and wrapped around soil bag facing combined with intercepting trench drains wrapped around with TS-50 geotextiles. In the second case (Case 2), the proposed pavement repairs consisted of intercepting trench drains wrapped around with TS-50 geotextiles combined with PEC-150 geotextile reinforcements of the gravel sub-base replacing the upper portions of the embankments underlying the pavements. The intercepted subsurface seepage lowered the water table and collected and safely directed the seepage flow to drainage pipes and channels.

Keywords: Embankment Failure, Internal Erosion, Road Failure, Drainage, Climate Change, Failure Mitigation

1 INTRODUCTION OF ROAD FAILURES

Road embankment and pavement failures occurred mainly during the widening of the road sections of National Road 1B (NR 1B) that connects Laos with China, along the portions passing through the soft shale deposits (see Fig. 1). The soft shale tends to weather into more clayey soils which is a problem soil with low shear strength and high compressibility. When wet, clayey soils generate pore pressures which decreases its shear strength.

Fig. 1. Location of National Road (NR) 1B from Laos to China border.

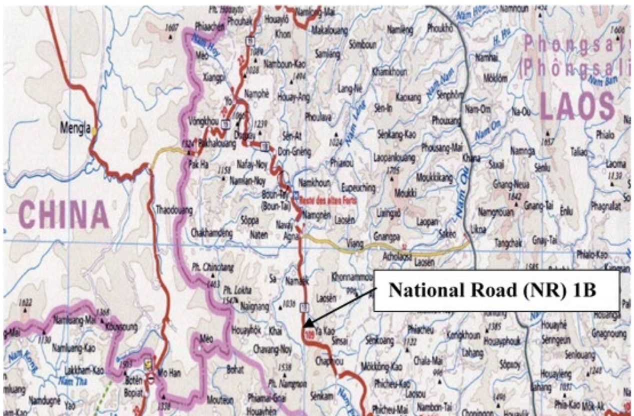


Fig. 2. Embankment failure due to underground water seepage and internal erosion at KM 49 to 50 (Case 1).

Fig. 3. Pavement failure due to wetting and large volume of water seepage under road pavement at KM 39 to 40 (Case 2).

Furthermore, clayey soils tend to lose its suction pressure when its moisture contents increase and, subsequently, decrease its shear strength further. Moreover, being fine-grained soils with low permeability, clayey soils are highly erodible.

Past design methods for roads across hillslopes emphasized achieving road with balanced earthwork i.e. equal cut and fill quantities. Thus, the contractor removed materials from the hillsides (cut) and placed it along the lower sides of the road (fill). During the widening of the road sections, additional cuts were made in the upper slopes and apparently were pushed into the lower slopes without adequate compaction and without erosion protection measures. During the rainy season, unusually high volume of rainfall runoff wetted, internally eroded, seeped below the road with consequent road embankment failures in the lower slopes as shown in Fig. 2 indicated as Case 1 located at the vicinity of KM 49 to 50. Moreover, in another road section, large volume of water seeped under the road and wetting in the lower slopes with subsequent widespread damage and cracking in the pavement of the newly widened road sections. These types of failures also occurred at thicker deposits of weak soil layers resulting in larger and deeper slope failures. Furthermore, some areas experienced excessive volume of underground seepages due to the presence of large catchment areas in the upper hillsides (Fig. 3) indicated as Case 2 located at the vicinity of KM 39 to 40. In these critical areas, the whole roads subsided and seriously damaged. In addition, slope failures also occur in the upper cut slopes. These problems occur every rainy season and needs immediate risk assessments so that mitigation measures can be formulated in the near future.

The objectives of this paper are to discuss two cases of successful mitigations and repairs using geotextile reinforcements as well as intercepting under drains with geotextiles. Related cases were published earlier by Bergado et al (2016, 2017).

2 GEOTEXTILE CRITERIA

Large permeability of the geotextile filter is desired but at the same time soil particles should be minimized from passing into the filter. The basic requirement of the permeability criteria is that the geotextile filter must remain more than the adjacent soil such that:

$$K_{geotextile} > K_{soil} \tag{1}$$

For applications in critical projects, the permeability of the geotextile should be at least 10 times greater than the corresponding permeability of the soil.

A geotextile clogs if soil particles are trapped within the fabric structure. Clogging can reduce the permeability of the geotextile. Current geotextile-soil retention criteria are generally based on the relationships developed between an indicative pore size for geotextile and grain size of the soil as follows:

$$O_{95} \leq 3\ D_{85} \tag{2}$$

and

$$O_{15} \geq 2\ \text{to}\ 3\ D_{15} \tag{3}$$

where:

O_{95} = 95% opening size of geotextile filter
O_{15} = 15% opening size of geotextile filter
D_{15} = diameter of the 15% particle size
D_{85} = diameter of the 85% particle size

For geotextile strength in both separation and reinforcement applications, the formulation of the allowable values takes the following form.

$$T_{allow} = T_{ult}\left(\frac{1}{RF_{ID} x RF_{CR} x RF_{CD} x RF_{BD}}\right) \tag{4}$$

where:

T_{allow} = allowable tensile strength
T_{ult} = ultimate tensile strength
RF_{ID} = reduction factor for installation damage
RF_{CR} = reduction factor for creep
RF_{CD} = reduction factor for chemical degradation
RF_{BD} = reduction factor for biological degradation

3 GEOTECHNICAL CONDITIONS

The field exploration, sampling and testing were done by the State Enterprise for Survey, Design and Material Testing (SDMT). Twelve boreholes (BH1 to 12) were done together with standard penetration tests (SPT). Furthermore, 25 dynamic cone penetration tests (DCP 1 to 25) were done mostly near the river bank at the corresponding locations of the SPT tests. In addition, six open test pits were excavated. The site investigations also specified the sampling and subsequent laboratory tests.

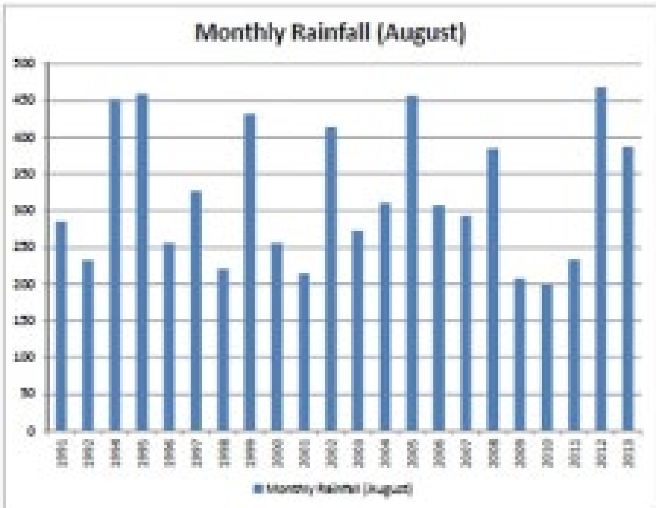
The results of SPT and DCP tests revealed an uppermost layer of yellowish red silty sandy clay of low plasticity with thicknesses of 5 to 6 m near KM 27 to 49 (BH2 to BH6) and KM 56 to 63 (BH10 to BH11) as well as from 10 to 12 m near KM 49.5 to 55 (BH8 to 9) as well as at KM 73 (BH12). The weakest topmost soil layers were found at KM 37+645 (BH3), KM 48+712 (BH5) and KM 49+593 (BH7).

The records of heavy rainfall data during August and September (1991-2013) are shown in Fig. 4a,b.

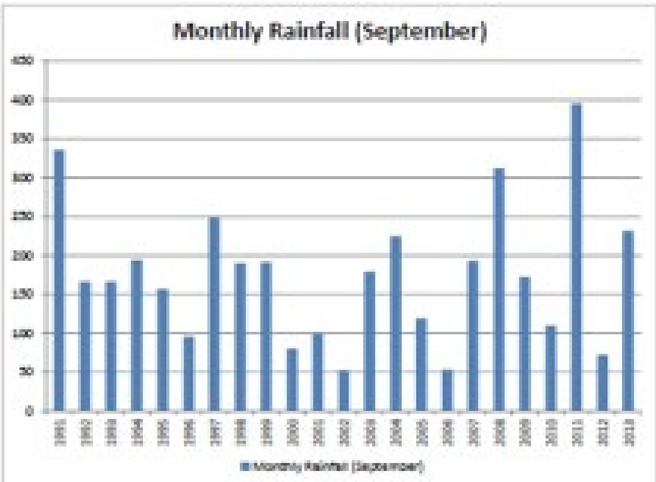
4 MITIGATION MEASURES FOR SOIL EROSION AND SLOPE FAILURES

The slope repairs were designed with geotextile reinforcements using PEC-150 consisting of nonwoven geotextiles combined with woven polyester yarns. The ultimate tensile capacity of the geotextile reinforcements PEC-150 was 150 kN/m and were laid out with vertical spacing of 0.5 m. The wrapped around geotextile facing were installed using jute or plastic bags with as illustrated in Fig. 5.

The trench drains consisted of gravel wrapped around with TS-50 geotextiles and were located at the road shoulders between the road and the adjacent drainage canal. The bottom of the trench drain must be located at lower elevation than the drainage canal in order to intercept the underground water seepages from the hillsides in the upper slopes (see Figs. 6 and 7). All intercepting trench drains must have at least 3% downward slope and properly connected to underground culverts beneath the road in order to safely discharge and drain seepage water towards the lower elevations.



(a) August (1991-2013)



(b) September (1991-2013)

Fig. 4. heavy rainfall data during August and September (1991-2013).

Fig. 5. Construction of reinforced slope involving jute bags as facing.

The backfill materials for the reinforced lower slope shall consist of free draining crushed sandstone with permeability not less than 10^{-4} cm/sec and less than 5% passing no. 200 sieve as well as with Unified Soils Classification (USCS) of poorly graded gravel (GP).

Two schemes were utilized to mitigate the failures, namely: Case 1 for road embankment failure due to underground water seepage and internal erosion (KM 49 to 50), and Case 2 for pavement failure due to large water seepage under road pavement (KM 39 to 40).

4.1 Case 1: Road embankment failure at KM 49 to 50.

The combination of 10m high geotextile reinforced lower slopes with gravel filled gabions or soil bags facing and trench drains (1.5m deep and 0.5m wide) was proposed at KM 49 to 50 with deep deposits of weak soil layers as shown in Fig. 5. Figure 7 shows the road embankment condition at KM 49 to 50 after 5 years.

4.2 Case 2: Pavement failure at KM 39 to 40.

Combination of geotextile reinforced free-draining gravel subbase and trench drains (1.5m deep and 0.5m wide) was used. The reinforcement consisted of PEC150 geotextile. Details of this scheme are given in Fig. 7. This scheme is intended for KM 39 to 40 where widespread damaged in the whole road sections were observed. Figure 9 shows the repaired pavement at KM 39 to 40 after 5 years.

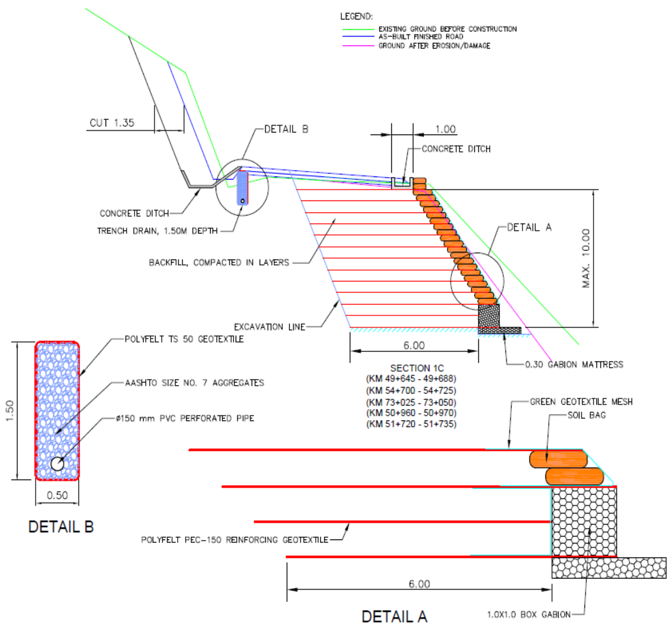


Fig. 6. Road embankment failure and internal erosion remedial works at KM 49 to 50 (Case 1).

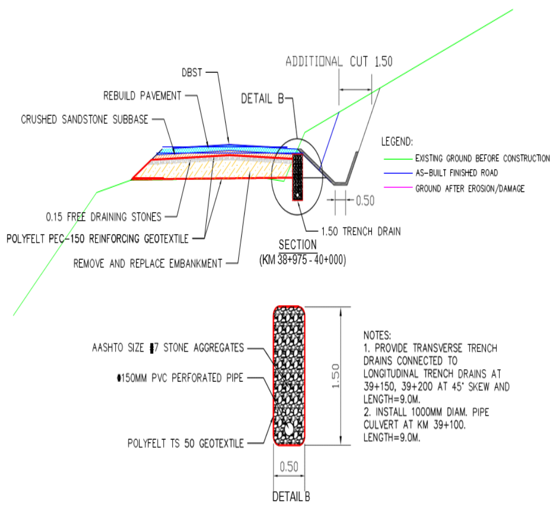


Fig. 7. Remedial works for pavement failure at KM 39 to 40 (Case 2).

Fig. 8. After repair of pavement and slope failure at KM 49 to 50 (Case 1).

Fig. 9. After repair of pavement failure at KM 39 to 40 (Case 2).

5 CONCLUSION

During continuous heavy rainfall, excessive surface runoff and subsurface seepage caused road settlement and lower slope failures as well as pavement subsidence, rutting and cracking which are referred as Cases 1 and 2, respectively. These failures occurred at around KM 49 to 50 (Case 1) and KM 39 to 40 (Case 2). The mitigations for Case 1 consists of geotextile reinforcements with gabions 1.0m by 1.0m cross-section filled with gravel at the base. In the upper slopes, soil bag facing with wrapped around PEC-150 geotextile reinforcements (Tult=150 kN/m) were utilized. The loose uncompacted soil fills were replaced by compacted crushed sandstones. Moreover, for Case 2, the proposed pavement repairs consisted of subsurface drainage to remove and control the flow of groundwater under the pavement as well as intercept with trenched drains wrapped with TS-50 geotextiles. In these schemes, the water table was lowered and the seepage flow were directed to drainage pipes and channels. The upper portions of the embankment were replaced by free-draining gravel sub-base reinforced with PEC-150 geotextiles.

REFERENCES

Bergado, D.T., Artidteang, S., Voottipruex, P. and Hino, T. (2016). Environmental improvement of geo-disasters due to climate change: From mountains to lowlands. Plenary Lecture, Proc. 10th Intl. Symposium of Lowland Tech., Mangalore, India.

Bergado, D.T., Chaiyaput, S., Voottipruex, P., Hino, T. and Chanmee, N. (2017). Mitigations of flooding and soil erosion geo-disasters in Thailand and Laos due to climate change: From mountains to lowlands. Lowland tech. Intl. Journal, Vol. 19, No. 1, pp. 63-76