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Acceptable movements of road embankments

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ABSTRACT: The stability of slopes and embankments under the influence of static and seismic loads has been the subject of study for many researchers. This paper stands for an attempt to present tolerable movements, based on caused damage on slopes of the embankments, as well as to connect them with natural disasters of the environment.

KEY WORDS: River embankments, road design, acceptable movements, levels of damages.

1 INTRODUCTION

As widely known, remaining earthquake deformations result from both shear failure and soil compaction (compassion). Consequently, the vulnerability of terrain structures can be correlated with deformations of the structure itself, while the size of the movement causing failure varies between different types of construction.

For the seismic design of embankment slopes due to shear failure, the geotechnical engineer can follow two methodologies: (a) to ensure a minimum safety factor and (b) to limit the territorial movement that construction will present during the earthquake (Stamatopoulos, 2003).

The purpose of this article is to record and present the acceptable movements of road ramps caused by seismic stimulation.

2 INFLUENCE FAILURES OF EMBANKMENTS ON THE ENVIRONMENT

There are many recorded cases of road embankments failures either due to poor condensation or due to seismic vibration and oscillation. As a result of the above, sliding, caving and rupture of the pavements that are based on the surface of the embankment. The impact of road degradation on the environment is important because it not only causes pollution in the atmosphere but also affects the ecosystems, fauna and flora of the area through which the road axis passes. In the following figures, failures of embankments and pavements from New Zealand (2017) and Kozani, Greece (1995) earthquakes are presented. Thus, environmental disruption can easily be ascertained, both during destruction as well as during restoration of the road network.

Figure 1. Earthquake damage to State Highway 1 is seen south of Kaikoura on Nov. 16.

Figure 2. Roadway rupture of the provincial road (Kozani earthquake, 1995)

Figure 3. Significant damages to the road network. (Kozani earthquake, 1995)

3 MAXIMUM ACCEPTABLE MOVEMENTS OF EMBANKMENTS

The maximum recommended acceptable seismic settlement of rivers, roads and railways embankments is given in the Tables 2,3,4 while the categories of constructions seismic damages are given in Table 1 (Stamatopoulos, 2003).

Table 1: Categories of constructions seismic damages

Categories	***Results***
A	Limited damages or easily repaired after seismic excitation damages (e.g. cracks) which they don't prevent constructions' usage and also do not pose risk to their stability
B	Damages which make defective and dangerous constructions' usage, yet construction is impossible due to cost

Table 2: Maximum recommended acceptable seismic settlement of rivers embankments correlated with its height H

Level of Damage	**Maximum settlement**	**Maximum settlement for H = 10 m**
B	0.05(H)	50 cm
A	0.01(H)	10 cm

Table 3: Maximum recommended acceptable seismic settlement of road embankments

Level of Damage	**Maximum settlement (cm)**
B	20
A	2.5

Table 4: Maximum recommended acceptable seismic settlement of railway embankments

Level of Damage	**Maximum settlement (cm)**
B	20
A	1.2

Matasovic in 1991 performed a natural slope stability analysis (using the flysch strength parameters) with the static method, the pseudostatic method, the Newmark sliding solid upon an incline method, and the simplified Ishihara method. In this study, he pointed out the important problem of considering a level of tolerable movement because the behaviour of a slope during and after the seismic vibration is associated with the choice of the shear strength parameters of the material and the exact calculation of the seismic load. He has adopted as limits of tolerable movements for natural slopes the following:

Table 5: Determination of acceptable movements based on the damage caused on natural slopes.

Effects/defects	**Acceptable movements (cm)**
Destructive	300
Serious	90
Medium	30
Small	15
Negligible	< 3

The international experience presented in the above table showed the following:

- Displacements up to 10 cm of sliding solids on an inclined plane analysis (Newmark, 1965) are considered to be unlikely to lead to landslides and destruction.
- Larger displacements of 10 to 100 centimeters can cause ground breakage or decrease in strength, resulting in the failure of the project.
- Finally, estimated movements of more than 100 centimeters should characterize the work as unstable.

In small dams and embankments, movements of a few centimeters or even a few tens of centimeters may be tolerable, provided the continuity of the dam filter is not interrupted.

In road and highway embankments, the horizontal ground movement should be no more than about 5 cm, above which unacceptable deformation of the road surface is caused. In B-road embankments, the permissible movement may be greater e.g. in the order of 10 centimeters, because: (a) the risk of an accident is lower due to the less frequent passage of vehicles and (b) traffic disturbance is of lesser importance.

If the ground needs strengthening the following tasks must be performed (Papaspirou, 2011):

Layers from selected geomaterials get down from pavements in replacement of natural soil with low strength or undesirable physical or mechanical properties. They aim to increase the subsoils strength, normalization or homogenization of the high level, drainage and frost protection.

The composition, structure and the name of the layer formed according to the aim pursued.

4. CONCLUSIONS

1. The maximum recommended acceptable seismic settlement of road embankments varies from 1.2 to 10 cm up to 20 cm depending level damage.

2. From the examples of the embankments failure, it has been found that it is difficult to predict, identify and categorize such slides and failures. The

reason for this lies with the difficulties associated with the determination of reliable parameters of the materials on the slip surface, the exact and inadequate characterization of the behaviour of the materials under irregular circular loads, and the uncertainty associated with estimating the seismic charges which are never clearly known.

3. The assumption of a tolerable movement level is surrounded by uncertainties as the behavior of a slope during and after the seismic vibration is associated with the choice of the shear strength parameters of the material and the precise calculation of the seismic load.

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