PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON ENVIRONMENTAL MANAGEMENT, GEO-WATER AND ENGINEERING ASPECTS
WOLLONGONG / NEW SOUTH WALES / AUSTRALIA / 8-11 FEBRUARY 1993

Environmental Management Geo-Water and Engineering Aspects

Edited by
ROBIN N.CHOWDHURY & (SIVA) M.SIVAKUMAR
The University of Wollongong, New South Wales, Australia

OFFPRINT

A.A.BALKEMA / ROTTERDAM / BROOKFIELD / 1993

Environmental Management, Geo-Water & Engineering Aspects, Chowdhury & Sivakumar (eds)
© 1993 Balkema, Rotterdam. ISBN 90 5410 099 0

Environmental impact of Roodbar landslide in Iran

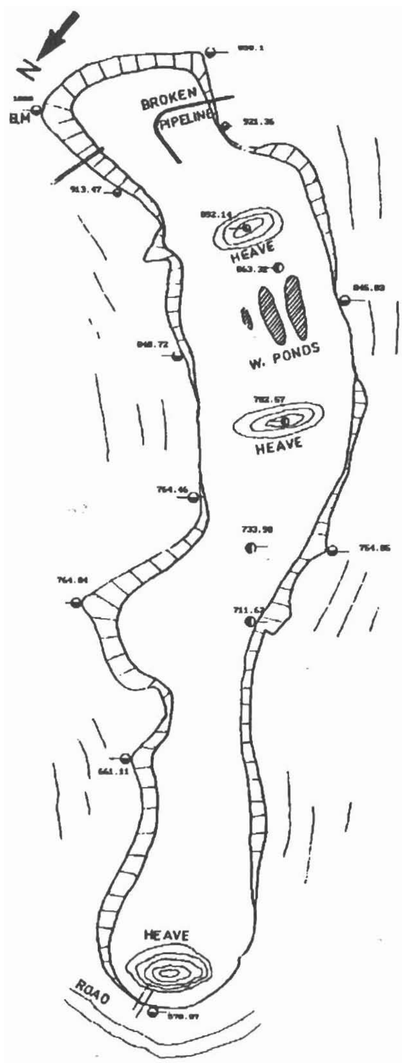
S.A.Anvar, L.Behpoor & A.Ghahramani
Shiraz University, Iran

ABSTRACT: The huge Roodbar Landslide happened during the M7.3 Manjil-Roodbar Earthquake in 1990. The earthquake produced the initial slip and the seepage of water and oil from the broken pipes initiated the slide. Unfortunately, no remedial steps were taken for improving the condition of slide except for rerouting the broken petroleum line. Continuous seepage of water into the slide has produced several ponds on the slide. Furthermore, the discontinuation of olive tree preservation on the slide has caused surface weathering and crack formation and the destruction of more than 50000 olive trees in this scenic region has had considerable impact on the environmental conditions. It is recommended to design lifelines in earthquake prone regions and on the slopes with special precautions.

Fig. 1 Roodbar landslide

1 INTRODUCTION

The devastating Manjil-Roodbar earthquake of magnitude M7.3, occurred on June 21,1990 and shook an area of about 600,000 square kilometers in the Northwest of Iran resulting in more than 30,000 loss of life , structural damages inflicted upon more than 100,000 homes, and leaving hundred thousands homeless. In addition, the earthquake resulted in liquefaction in vast areas and several major landslides which caused damages to buildings, environment and lifelines



B. M. ELEVATION = 1000 m.

ELEVATION OF NATURAL GROUND

ELEVATION AFTER SLIDING

Fig. 2 Slide geometry

in the region.

Roodbar landslide, one of the biggest landslides yet reported in Iran in recent years, 2 km long, 300 m average width (ranging from 200 to 500 meters), and 10 m average depth (ranging form 5 to 30 meters) happened in the region. This slide has moved more than 5 million cubic meter of soil, with a movement at some points reaching 400 meters.

A brief description of this landslide together with the results of soil properties measurements and stability analysis were reported by the authors (1992). In the present paper, the geometry of the landslide measured by land survey is presented.The mechanism of the slide is discussed and the effect of oil on strength reduction of soil is studied and it is postulated that the penetration of oil from a petroleum lifeline, broken during the earthquake, could be one of the contributing factors in triggering the slide 48 hours after the main shock of earthquake. The impact on environment is discussed and recommendations are offered for designing lifelines in earthquake prone zones and on the slopes.

2 MECHANISM AND CHARACTERISTICS OF THE SLIDE

According to measurements and analysis carried out previously by Anvar, Behpoor and Ghahramani (1991) and recent investigations, the mechanism and characteristics of the slide can be summarized as follow. An overview of the slide area is shown in Fig.1 and the slide gometry based on new field survey of the Roodbar slide is presented in Fig. 2.

1. The initial average slope of the ground of about 20 degrees has been reduced to about 15 degrees in upper part after the slide occurrence, the movement being up to 400 meters.

2. By considering ground topography, measurements of soil properties, and using finite element and slope formulas it was shown that the slope had a factor of safety of about 2.6 prior to earthquake.

3. The acceleration of earthquake was reported to be 0.65 g at the station 65 km away from the area. Using this horizontal acceleration, calculations showed that the safety factor during the earthquake was reduced to 1. Although the slide did not occur during the earthquake, the earthquake acceleration could produce an initial slip.

4. After the earthquake, using the residual strength the slide had a factor of safety of about 1.8. Thus after initial slip which occurred during earthquake and its after shocks, the slope was still stable.

5. The petroleum pipeline located in the upper part of the slide was broken during the earthquake (most probably as the consequence of the initial slip). Petroleum flew to the body of the

slide and continued to flow for 48 hours before the start of the slide.

6. 48 hours after the earthquake, the reduction in soil residual shear strength due to petroleum and water penetrations resulted in dropping of factor of safety below unity. Consequently the slide was triggered and continued for almost a month before coming to rest, during which local heaves and water ponds were created.

7. The slide destroyed several houses and irrigation ponds and about 50,000 olive trees and resulted in a considerable damage to the environment (see Fig. 1). It is to be noted that the petroleum line was repaired and rerouted within the first month, (see Fig. 3).

Fig. 4 shows the variations of safety factor in time sequence.

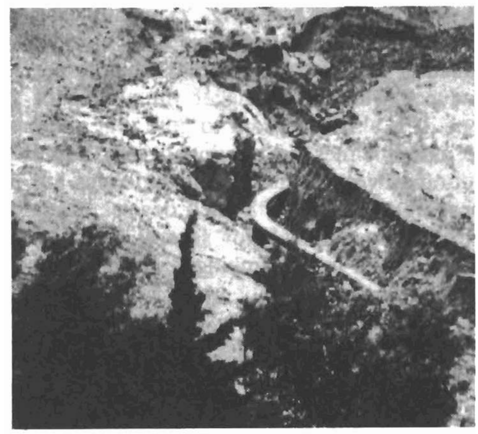


Fig. 3 Rerouted petroleum line

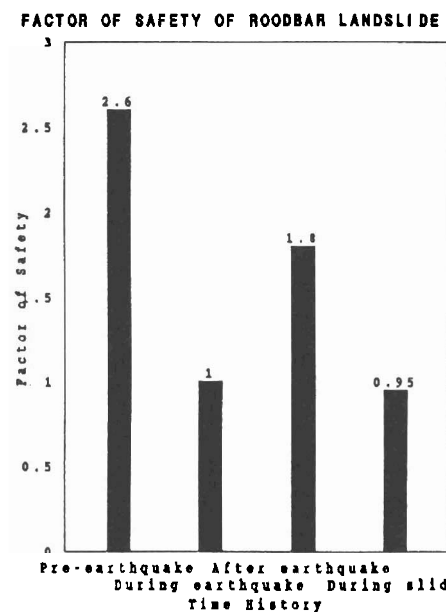


Fig. 4 Time sequence of factor of safety

3 DISCUSSION

The Roodbar earthquake and consequent landslide showed clearly that the design of lifelines, especially gas and petroleum lines, in areas prone to earthquake and on slopes need special attention. Gas line rapture may cause explosion with subsequent damages to the environment and even loss of life. The breakage of gas line due to landslides, at least, can shut off the natural gas supply to urban areas and industrial consumers causing severe discomfort. Behpoor and Ghahramani (1988) reported a gas line rapture in Iran together with the stability measures performed to prevent future sliding in new gas line location.

Breakage of petroleum lines can cause landslides and severe damage to the environment. In the case of Roodbar, the petroleum line rupture resulted in the penetration of the oil in the fissures and subsequent reduction of the angle of internal friction and cohesion of the soil. In Roodbar before the earthquake soil parameters were c = 140 kpa and angle of internal friction ϕ = 27.5 degrees. After the initial shock of the earthquake the strength parameters were reduced to residual, c= 100 kpa and ϕ = 20 degrees. However the slope had still sufficient factor of safety to be stable after the earthquake. The infiltration of petroleum and water reduced the angle of internal friction and cohesion with subsequent triggering of the slide. The soil samples which were taken from the slide area were tested. The hydrometer test shows the existence of petroleum (see Fig. 5) To further study this phenomenon, the soil samples taken from the slope were mixed with different amount of oil and strength parameters were measured. Fig. 6 shows the results of this study. It is clear that a small amount of petroleum would considerably reduce the strength parameters. It should be noted that petroleum does not ordinarily penetrate deep into the soil due to high viscosity, however the existence of tension cracks due to either weathering or earthquake as in the case of Roodbar (see Fig. 7) would ease the penetration of petroleum and subsequent reduction in soil strength, thus weak zones are produced which may trigger the sliding of the slope. It is also important to note that although the gas pipelines are equipped with automatic shut-off valves, the petroleum pipelines are not normally equipped with such devices, therefore petroleum could leak for several hours before being shut off from pumping stations.

4 ENVIRONMENTAL IMPACT OF ROODBAR LANDSLIDE

The Roodbar area is located in the South of Caspian Sea endowed with forests, beautiful landscape, rivers, fruitful agricultural fields and olive trees on the slopes. These have made an attractive environment being used also as a resort area by Iranians during summer months. The income of many residents in the area is basically dependent on olive trees. The slide has destroyed more than 50,000 olive trees and the penetration of oil has affected many others. As the conditions are similar in many neighboring areas adequate measures should be taken to prevent landslides and lifelines should be designed with earthquake considerations.

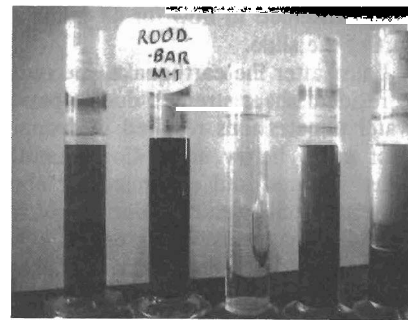


Fig. 5 Hydrometer showing oil content

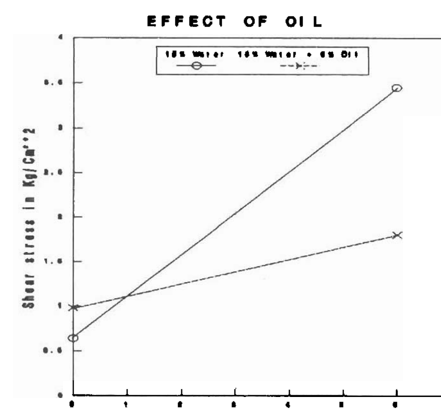


Fig. 6 Shear strength with oil

5 CONCLUSIONS

Based on the study of Roodbar landslide it is concluded that:

1. The earthquake of 0.65 g caused an initial slip and tension cracks and reduced the soil strength parameters to residual.
2. The petroleum penetration due to rupture of pipeline as a consequence of earthquake reduced soil strength parameters producing weak zones and reducing the factor of safety of the slope. This triggered the landslide 2 days after the earthquake.
3. The environmental impact and the economical loss to the area was considerable.
4. The slide destroyed some houses and water pools and about 50,000 olive trees with considerable damage to the environment.

6 RECOMMENDATIONS

Considering that lifelines are of fundamental importance to economic growth in developing countries, the following recommendations are made.

1. Special attention should be given to design of lifelines in earthquake zones and on the slopes. The lifelines should be equipped with its own independently operated communication lines as is practiced in South of Iran.
2. On slopes in earthquake zones, the petroleum and other lifelines should be equipped with automatic shut-off valves to be activated in case of rupture.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support of the School of Engineering of Shiraz University and the Power and Water authority of The Guilan Province. The efforts of Mr. Tortiz and Mr. Rezanejhad is acknowledged.

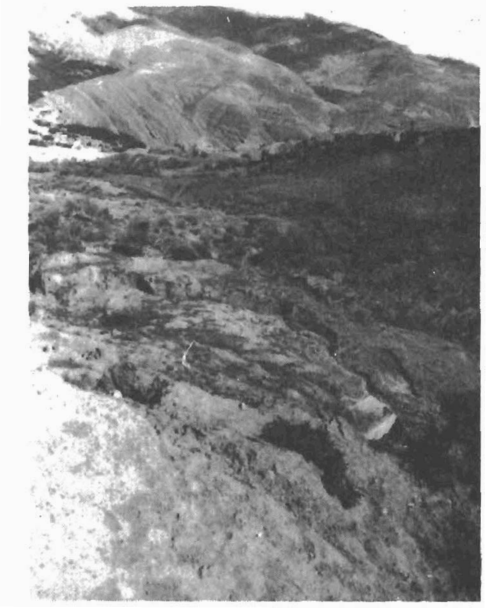


Fig. 7 Tension cracks on the slide

REFERENCES

Anvar, S.A., L. Behpoor and A. Ghahramani 1992. Landslide in recent Roodbar earthquake in Iran. Sixth international symposium on landslides. New Zealand: Balkema.

Behpoor, L. and A. Ghahramani 1988. Landslide and stabilization at gas pipeline station 201 in Iran. Fifth international symposium on landslides. Switzerland: Balkema.