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Landslide and stabilization at gas pipeline Station 201 in Iran

Glissement de terrain et stabilisation à la Station 201 d'une conduite de gaz en Iran

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ABSTRACT: The gas pipeline in Fars province of Iran was disrupted by a landslide in 1978. The location of the pipeline was changed but the new site was also in danger of sliding. The authors were consulted to stabilize the region. The stabilization scheme consisted of a drainage system and a retaining structure. The retaining structure consisted of a wall of 4 inch steel pipes backfilled with cobbles and boulders and supported by 9 vertical 16 inch steel pipes burried in boreholes filled with concrete. The stabilization scheme provided cost effectiveness, speed, ease of construction and efficiency of drainage. Construction works were completed in 1985 and since then the slope has remained stable in spite of the very rare heavy rainfall and snowfalls occurring in this period.

RESUME: Une conduit de gaz a été rupture par un glissement de terre dans le province de Fars en 1978. Alors que l'emplacement de cette ligne a été changé, mais le nouvel emplacement aussi avait le risque de glisser. Les auteurs ont été consultés pour stabiliser la region. Le projet de l'stabilisation a été composé d'une systeme de vidange et une structure de retenir qui est composée d'une muraille de 4 pouces tuyaus en steel supportée par 9 tuyau vertical de 16 pouces diameter. Ces dernier tuyaus ont été emplace dans des trous rempli par béton. La derrier de ce maillage a été rempli par des rocher et pavé rond. Ce projet avait quelques avantages surtout en reduction de dépens, la durée et facilité de construction et aussi l'efficacité de vidange. La construction a été terminée en 1985 et malgré de quelque trés lourde pluie et neige elle est complétement rigide.

1 INTRODUCTION

At station 201, the gas pipeline from Gachsaran to Shiraz (in Fars province of Iran) was disrupted by a landslide of about 30,000 cubic meters resulting in gas supply cut off in Shiraz and its related industries (1978).

Another line was established further up the escarpment in the highly tectonized zone. Movement of this line resulted in the establishment of the third path further up the escarpment. But this line was also in danger of sliding and there was no possibility to go further up.

The writers of this paper were referred to by the authorities of Iran Gas Company to investigate the situation in order to stabilize the pipeline route in 1984.

2 INVESTIGATIONS

Several visits to the site by land and by helicopter were made by the authors. The topographical maps of the area and the geological maps were not sufficient for analysis, therefore geology and land formations were thoroughly investigated. Aerial photos and slides taken by helicopter from different angles were used to study the area.

The area is in the highly tectonized "Crushed Zone of Zagross" and is at the southern flank of a fault embedding a river and showing at northern side the outcrops of Asmari Formation (thin bedded low weathering limestones alternating with thin marlstones; oligocene epoch).

At the southern flank where gas pipeline No. 3 is located, there is a steep escarpment interbedded with ridges of limestone, but mostly composed of marl and shale of Pabdeh Formation (weathering shale, marls and marlstones; thin bedded limestones; Paleocene and Eocene epochs). The laminated shale is highly fossilated. After the escarpment the slope reduces to 23 degrees and flattens to 10 degrees at bottom of the valley. The sliding areas were divided into three zones as presented in Fig. 1.

Zone No.1: Sloping 20 degrees where gas line No.1 was located is mainly composed of green laminated Pabdeh shale. The major slide in the location resulted in movement of about 30,000 cubic meters of soil and 300 meters of movement. The slide happened after a heavy rainfall, reducing the angle of shearing resistance to 15 degrees and eliminating cohesion of the shale, thus resulting a mud flow. This slide resulted in disrupting the gas supply.

Zone No.2: Located between the top of Zone No.1 and the bottom of Zone No.3, is the region where gas line No.2 is situated. Evidence of instability were noticed such as the outcrops of green Pabdeh shale, a slope of about 18 degrees and curvature in lines of plants. The area is also the site of water collection of the escarpment. Small scale slides were also noticed at the bottom of this zone were gas pipeline No.2 (not in service at present) is located.

Zone No.3: This is the zone that locates the present gas line and where the stabilizing efforts were carried out. It is shown in Fig.2. The slope is steep,the general slope is 23 degrees and route No.3 passes parallel to the toe of the escarpment in this region. Due to the importance of this region as the only possible location for the gas pipeline,the area was investigated precisely and in detail. Evidences of local outcrops of limestone ridges were noticed in the main land formation of green Pabdeh shale. The area was investigated originally by four hand dug wells to depth of 6 meters. The results of analysis of soil profiles of the wells showed that a horizontal limestone bed was located at the bottom of the zone, 4 meters beneath gas pipeline. However the bed was overlaid by the shales and rockfalls and did not outcrop in the surface. Due to the importance that this bed could have on the stabilizing efforts, further 9 wells were dug to depths of 4 to 6 meters parallel to the roadfill (and hence parallel to the gas line) at the toe of the slope and the existence of the limestone bed was established. (These wells were planned to be dug in such a manner that were later used as foundations for retaining structure).

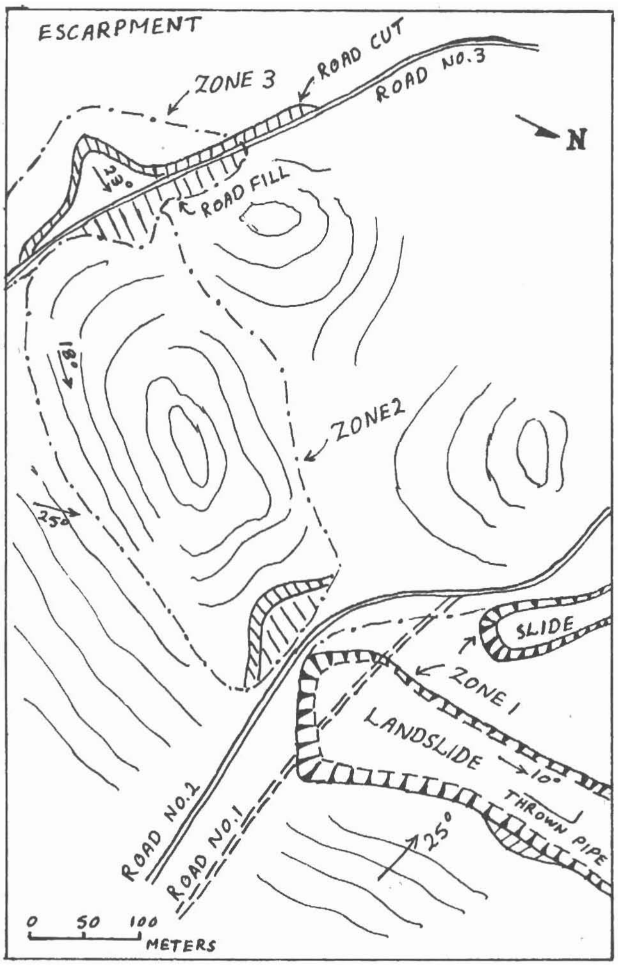

Fig.1. Sliding areas divided into 3 zones.

3 ANALYSIS

Considering the dessicated and laminated nature of the green shale and the slope of the regions where slide had occurred, it was concluded that introduction of water into the shale formation had reduced the cohesion to about zero and the angle of internal friction to about 15 degrees. Clay content (percent of particle less than 2 microns) found by hydrometer analysis was about 30 percent, which was in accordance with the conditions of sliding reported by Skempton (1964). Thus the basic preventive and stabilizing method was drainage; considering also the ridge of limestone underneath the pipeline, retaining of soil and tying it to the lower limestone bed by the help of a retaining structure was also important.

4 STABILIZATION SCHEME

Two stabilization methods, drainage and retaining structure at the toe of the slope were used.

4.1 Drainage

The choice of drainage was because of the very adverse effect water had on the strength of the green shale (reducing cohesion to zero and angle of shearing resistance to 15 degrees). Subsurface drainage scheme was not applied because of the disturbance it might have on the existing pipeline and very low permeability of the soil. Surface drainage was applied because most of the water coming down the escarpment was guided to the pipeline area.

One interceptor drain was constructed at the top and

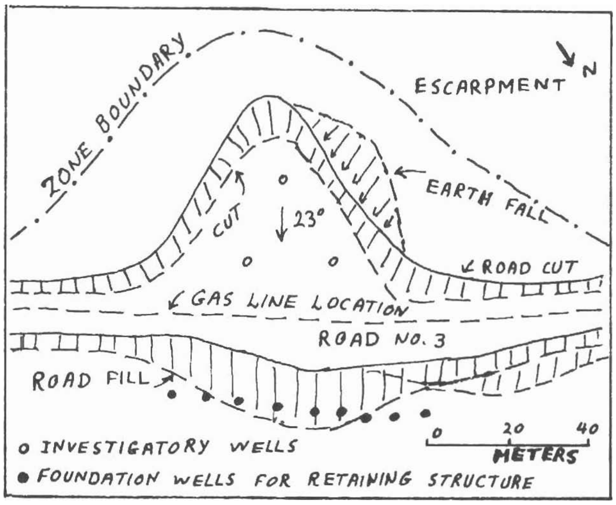

Fig.2. Zone No.3.

another one on the road near the pipeline. Both of these lines were channels of lean concrete lining and they both were connected together into natural drains at periphery of Zone 2 (Fig.3).

4.2 Retaining structure at the toe

At the toe of the slope, the series of nine wells of one meter diameter and 4 to 6 meters depth at spacings of six to eight meters were used as foundations of retaining structure. In each well a 16 inch diameter steel pipe was installed and filled with concrete. The outer periphery of the pipe was also filled with concrete up to the surface of the ground. Hence nine pipe columns were made, the height of each above the ground surface equal to 2 meters and each extending in the ground down to the limestone bed. To these columns 4 inch steel pipes were welded horizontally with 4 inch clear space between any two adjacent horizontal pipes. This retaining structure was backfilled with crushed stone and the slope of the roadfill was flattened to the top of the retaining structure (Fig.4).

The choice of using wells as foundation of the retaining structure was based on the fact that these wells were needed in the locating the underlying limestone bed, and also because a continuous foundation for the retaining structure would possibly disturb the integrity of the slope.

The choice of steel pipes for construction of retaining structure was because of the availability of steel pipes rejected for use as gas pipeline, but structurally strong enough for use in the retaining structure. It should be noted that the availability of suitable material for construction of retaining structure was important because of the remoteness of the region. In addition, pipe selection as construction material made it possible to use the highly skilled Gas Company maintenance crew who are well equipped and trained for pipe welding and installation. The ease of replacement in case of bulging or rupture of the connections is another advantage.

The stability calculations for the retaining structure showed such arrangement to be suitable.

Flattening the roadfill slope to the top of the retaining structure and backfilling the retaining structure with crushed stone would facilitate the drainage of water from rains or snowfalls.

4.3 Additional measures

Slopes cut by road construction were flattened and debris removed. Two bench mark nets were installed using the channel structures as foundations for

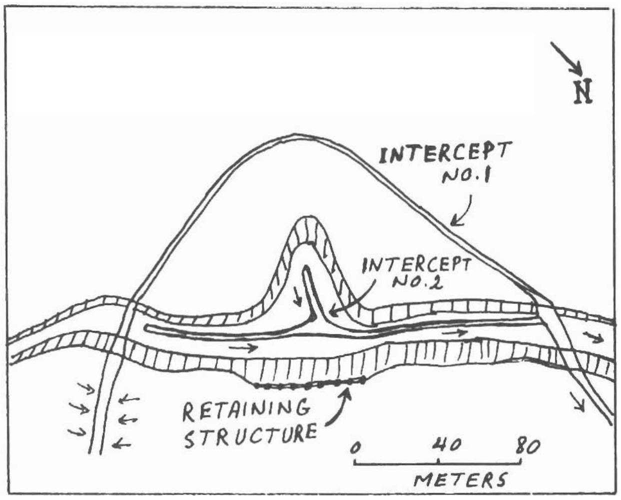

Fig.3. Drainage system.

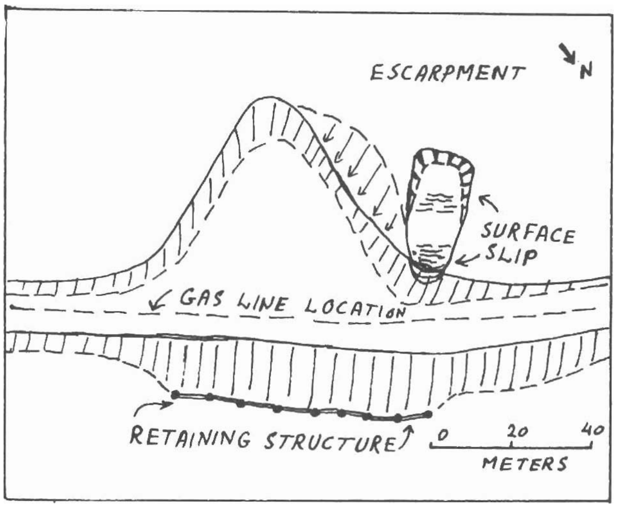

Fig.5. Surface slip at Zone No. 3.

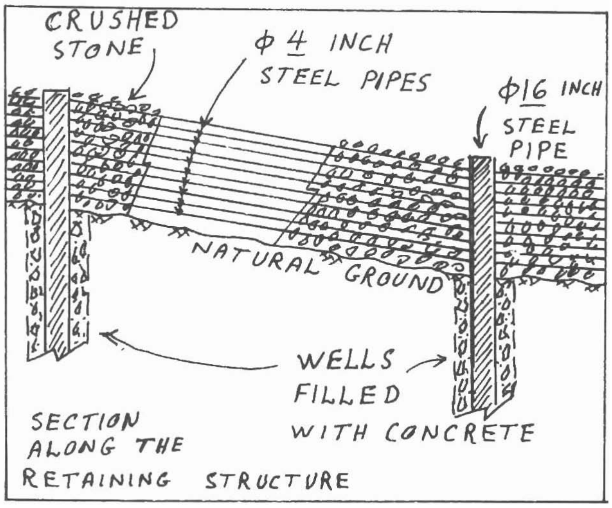

Fig.4. Retaining structure.

future investigation. Pipe locator (earphone type) was used by the maintenance crew of the Gas Company to investigate any possible movement. The maintenance engineers also visited the site regularly.

5 AFTER-EVENTS

Construction of the stabilization scheme were finished in August 1985. All of the stabilization works were carried out by the engineering and maintenance crew of the Iran National Gas Company and the authors visited the site during construction works repeatedly.

In the winter of 1985 a heavy snowfall (80 cm) happened in the region and in the winter of 1986 a very rare heavy rainfall (heaviest in last 40 years of 25 cm in two days in an area of average yearly rainfall of 35 cm) happened. The slope fortunately remained stable.

In the spring of 1987 a surface slip occurred at location shown in Fig.5. The slip affected a 14 by 25 meters area and 2.5 meters depth. The earth removal scheme which has been carried out previously and the road cut triggered this slip. If the stabilization scheme has not been applied, the slip could be more extensive and possibly could have cut the gas line. Fortunately the slope remained stable showing the effectiveness of the scheme applied.

The progression of slope instability at the zone of gas line No.2 (not used for gas presently) is continued and as predicted has made line No.2 quite unstable.

The site visit showed that drainage channels worked properly. This was due to the fact that the maintenance crew intermittently cleaned the debris in the channels. The retaining structure also showed no evidence of rupture at welded pipe connections.

6 CONCLUSIONS

The following conclusions can be made:

a) In highly tectonized zones like South-West area of Iran, detailed soil engineering and geological investigations may reveal possible stable locations in highly unstable regions. In the area discussed in this paper the locating of a limestone ridge and tying the slope through a retaining structure to this ridge were the consequences of such studies.

b) In regions with shale formations and with dessicated and laminated structure, the drainage scheme is one of the most useful methods of slope stabilization.

c) The type of the stabilization scheme and retaining structure used in this project, i.e., installing pipe columns with horizontal pipe bracings, has the advantages of cost effectiveness, speed, ease of construction, ease of drainage, and in this case the availability of materials.

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