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Discussions and Replies Session 5

Shamsher Prakash
Missouri University of Science and Technology, prakash@mst.edu

J. N. Gómez
Javeriana University, Bogotá, Colombia

Eyjolfur Arni Rafnsson
Honnun Ltd., Consulting Engineers, Iceland

Roy E. Olson
University of Texas, Austin, Texas

DISCUSSIONS AND REPLIES

SESSION V

Discussion by Shamsher Prakash
Prof. Civil Engineering Dept.
University of Missouri-Rolla

on
"Braced Excavation at the NIPSCO Bailly Station Power Plant"

Paper No. 5.25

Reconstruction of intake and discharge lines at NIPSCO plant was interesting, but the original collapse of the pipes would also be an interesting case history.

What can you tell us about the collapse of the pipes, and what can we learn from it?

Discussion by Sanjeev Kumar
Assistant Engineer,
Punjab State Electricity Board,
Punjab, India
on
Failure of Twenty-Foot High Wall: Learning From Case Histories

Paper No. 5.31

"A little knowledge is a dangerous thing" this proverb has been proved by the author here. A double cantilever wall system with a lower wall of about 16 ft height and above that a wall of about 10 ft height, in central Texas collapsed after a period of rain fall, within two months of its completion. The reason was inadequate design. The wall system was designed by a registered professional engineer who was a generalist and did design work in most areas of civil engineering, but was not trained specially in geotechnical engineering. the designer literally followed the recommendations in the standard handbook for civil engineers without understanding the limitations of such design and apparently saw little need to perform extensive soil tests.

Main shortcomings in the design reported by the author were 1) two wall sections were analyzed separately and the effect of upper wall on the lower one was ignored 2) no slope stability type analysis were performed to examine the possibility of an overall failure 3) improper drainage system to drain water from the back of the wall and 4) high wall-soil friction coefficient.

Since there was an interest in getting the project in operation and the wall may have been a late addition to the design, there might not have time to perform extensive soil tests. But even then, I am of the opinion that if the designer had the knowledge of the behavior of the soils under different drainage conditions and design of retaining walls, this damage could have been easily avoided by simply considering the effect of upper wall on the lower one and by providing the proper drainage system. Any engineer who has basic concept of forces and moments, can not make a mistake of ignoring the effect of upper wall on the lower one. Provision of proper drainage system definitely requires the knowledge of geotechnical engineering.

The designer also designed a cantilever retaining wall exceeding 26 ft in height for some of the portion in the same project. Cantilever retaining walls are uneconomical above 20 ft height of wall. Provision of counterfort retaining wall would have been more appropriate.

Failure is a full scale destructive test and gives useful information to guide future endeavors. It is lesson for which price has already been paid. If the similar failure can be avoided by learning a lesson from the earlier failure, this can be considered a price to progress. This case history once again reminded that a work in the hands of a amateur will lead to mess.

**Discussion by J. N. Gómez S.
Partner, Geotechnical Branch
C.I.C. Ltda, Bogotá, COLOMBIA.
Professor of Advanced Soil Mechanics, Javeriana University, Bogotá, COLOMBIA.**

on
Failure of a Twenty-Foot High Retaining Wall

Paper No. 5.31

The failure of a double cantiliver retaining wall is presented. The upper wall (UW) is 10 ft (3 m) high and the lower one (LW) is 16 ft (5 m). Total wall system height is 26ft (8 m). It failed in a length of about 100 ft (30 m). Soil investigation at the site was rather poor: borings were not drilled and test were limited to soil classification. The design of the wall system had basic erroneous assumptions such as to consider the walls separately rather than designing the LW taking into account the active effect of the UW on it. On the other hand, no overall stability analysis was performed.

The author carried out a site investigation, reviewed the original design and undertook a design of the LW taking into account the effect of the UW. The scope of the study included two phases: the first one dealt with the calculation of the lateral force upon the LW imposed both by the weight of the soil wedge above it and the UW, and the second one, consisted in evaluating the safety factors of the LW against overturning, sliding and bearing capacity. There was not sufficient information such as the original soil profile, to perform a realistic overall stability analysis.

The work is valuable, well documented and comprehensive. A cross section of the site, however, showing the idealized soil profile after failure, obtained from the results of the site investigation would have been helpful. Figure 1 summarizes the results of the author's analysis in terms of safety factors for drained and undrained conditions. It is clear that the LW could not be stable from the bearing capacity and sliding points of view. It was founded on weak soil and supporting a load of about 15 kips/ft (22.4 ton/m).

The writer would stress among other facts included in the paper, that special attention has to be paid to bearing capacity and sliding checks, rather than following common and established practice of calculation for retaining wall design presented in many civil engineering books. When geotechnical parameters are involved in the design of a structure, geotechnical judgment and expertise coupled with a site investigation program are important in order to understand the behavior of it and to select the appropiate strength of the materials involved.

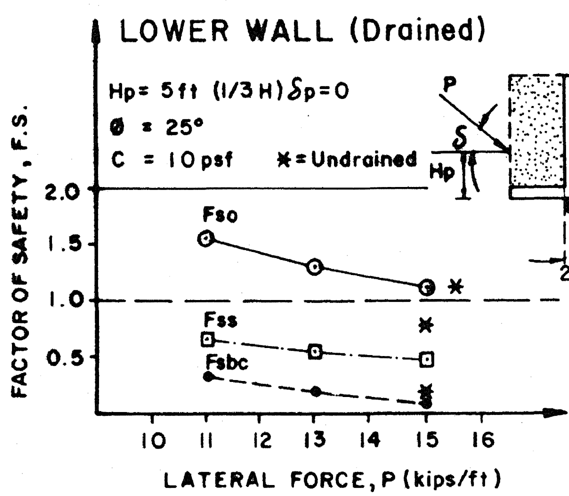

Figure 1

Discussion by Dr. Eyjolfur Arni Rafnsson
Hönnun Ltd., Consulting Engineers, ICELAND
on
Failure of a Twenty-Foot High Retaining Wall

Paper No. 5.31

A failure of 20' high retaining wall, designed and constructed to provide area for parking spaces and driveways for a shopping center in central Texas, has been discussed in this paper. The failure "led to losses in excess of $1 million for the designer". The retaining wall was a 1300' (~400 m) long with a maximum height of 26'9" (~8.2 m), measured from the top of the keyway. The presence of a high concrete wall was objected by the city environmentalists. Thus, a relatively low single wall was designed over much of the length and where the wall was higher than about 15' (~4.6 m) a double wall was designed, over 700' (~210 m) long. A vegetation was planned in between the two walls. Site investigation for the wall design was limited. The designer practically followed the Standard Handbook of Civil Engineers, by Meritt. Factor of safety against tilting was sufficient, calculated about the toe. The effect of the upper wall on the lower one was ignored, overall stability was ignored, sliding factor of safety was only about 1.0, the toe stress was high. Drainage was, for both walls, provided by 2" diameter PVC drainage tubes. The wall is believed to have been completely backfilled in May. In late July, after a period of heavy rain, a 135' (~41 m) long section of the lower wall began to displace horizontally. The wall continued to move horizontally at a slow rate. Post-failure soil investigation showed that the fill, which not failed, was partly a dry granular fill. The fill that had failed was soft rocky clay, havingf LL=54, PL=33, and wc=31 %. The fill seemed to be "reasonably well compacted". Drained direct shear tests (4) showed both peak and residual effective cohesion as 100 psf (4.8 kPa), but effective friction angle as 25° and 16° for peak and residual conditions, respectively. Post-failure stability analysis of the retaining wall showed that factor of safety against tilting was sufficient while it was far from being sufficient against sliding, bearing capacity, and overall stability. It should be kept in mind that actually only the lower wall is of a concern. The main conclusion of the paper, that "engineers should not practice out of their areas of training and experience", is a necessary warning that always should be kept in mind. Why did the wall stand up at all? It is the discusser believe that negative pore pressure may have helped initially. Following the rain a positive pore pressure, ineffective drainage system, and the designer lack of knowledge was the main cause of the wall failure. The paper should be read by every engineer as a lesson on how things can easily go wrong although they look simple.

Reply by R. E. Olson
on
Paper No. 5.31.

In his discussion, Mr. Gomez asks for more information on an idealized soil profile. In the immediate area of the failure, the wall was underlain by a deep layer of clay shale, possibly as much as 100 m thick. In the upper ten meters, the clay shale contained seams of limestone with the thickness of each seam about 10 cm, and a vertical spacing of the order of one meter. Some borings showed similar seams of gypsum. Standard penetration resistances at shallow depth were 67 to 87 blows/30 cm and unconfined compressive strengths on cores were usually around 520-570 kPa (5.5 to 6.0 tsf). Along most of the length of the wall, where failure did not occur, the ground surface was higher then in the failure zone, the wall therefore not so tall, and the wall was underlain by up to 3 meters of solid limestone overlying the deep shale.

Mr. Gomez emphasized the need to consider sliding and bearing capacity failure modes. The author agrees and emphasized in the paper the difficulties associated with attempts to calculate, and limit, toe stresses instead of considering the overall bearing capacity mode of failure.

Mr. Kumar observed that cantilever walls of this height are not economical and suggested use of a counterfort wall. Design calculations, obtained during litigation, gave no indication that the designer considered other alternatives. It appears that cantilever walls were used because they were covered in the civil engineering handbooks. However, counterfort walls would generally not be economical in the United States because of the increased labor costs. During the remedial phase of the work consideration was given to using reinforced earth and other walls with shallow foundations and tie backs but none were stable in the bearing capacity mode. Finally, the natural slope was reformed and the parking was provided on a structural slab constructed out over the slope. The slab was supported on deep drilled piers.

Dr. Rafnsson believes that the wall was initially stable because of negative pore water pressures in the backfill. The paper includes several reasons why the wall stood up in spite of low calculated factors of safety. The fourth reason listed was negative pore water pressures in the backfill. The rainfall that immediately preceded the failure apparently diminished these negative pore water pressures and also increased water pressures directly in the walls.