Problems Encountered in Diaphragm Wall Excavation

by

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Diaphragm walls or what is called slurry trenches are deep extended walls through granular or soft soils in shallow water table areas. Construction of these slurry trenches involves extracting a trench while simultaneously keeping heavy viscous slurry (bentonite) filling the excavation to provide lateral pressure that must be at least equal to or greater than the lateral pressure of the trench walls. In the construction of such kind of walls, excavation is the most serious problem encountered. In this paper the authors tried to focus on the most important problems involved in excavating diaphragm walls and providing some solutions.

1. Introduction

Bentonite slurry which is used mainly in oil drilling industry is proved to be an effective material in diaphragm walls construction[1)]. The main advantage of diaphragm walls technique is to avoid a huge excavations in places where excavation is difficult or impossible to be performed. This method of wall construction has had a great success since its first use[2)]. The following factors have led to this successful development :

a) The availability of bentonite produced from montmorillonitic clays and refined and converted to sodium montmorillonite,

b) The need of walls for deep basements, underpasses, and tunnels,

c) The development of excavation machines and development of bentonite processing plant.

It is also very applicable in places where dewatering cannot be performed. However, the construction of the diaphragm walls is always accompanied with a lot of difficulties and problems which are based mainly on how to estimate the deformation of the trench sides. Based on the calculated deformation the engineer will be able to design and determine the density and the other specification of the bentonite to be used. In construction of the diaphragm walls, there are a lot of things to be considered a side from the deformations. In this paper the authors tried to present the major problems encountered in the excavation of such kind of walls based on available information obtained from a case history three years ago under a large car park project in Almadenah Almonawarrah, Saudi Arabia.

2. Site preparation

Before starting the excavation, a central bentonite slurry plant must be prepared for mixing and providing bentonite to the trench or panels under excavation through a net of steel pipes with about 15-20 cm in diameter. This pipes system is spread a long the working areas to facilitate providing fresh bentonite and taking out used bentonite to be recycled by separation of rock fragments and sand fractions mixed with bentonite during the proccess of excavation as shown in Photo 1. Sand and rock fragments are usually separated by means of what so called desonders which is considered as an important unit of the bentonite plant.

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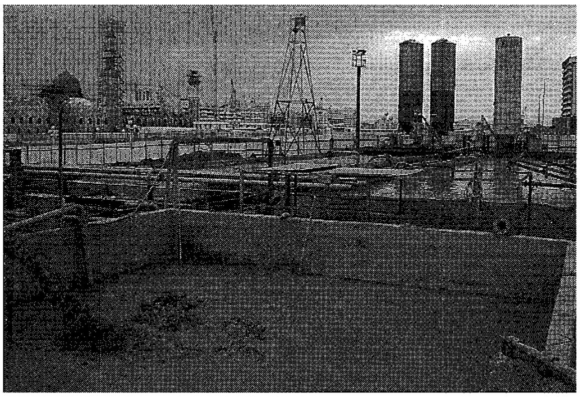

Photo 1 Bentonite plant.

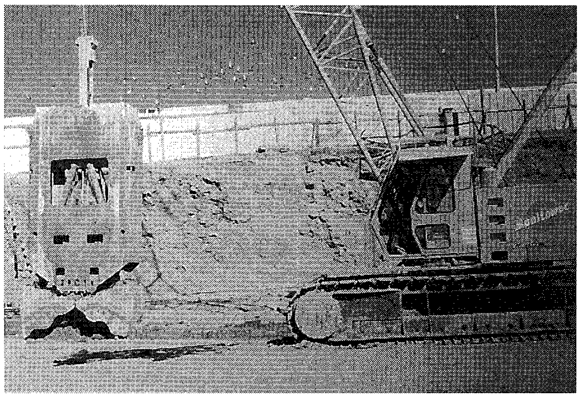

Photo 2 Grab which is used mainly in excavating loose sand.

3. Excavation

After the site exploration and investigation excavation starts, at this stage it must be decided what kind of excavation machines must be used in order to achieve the basic requirements for a minimum disturbance of the soil around or surrounding the trench. As an example of that loose sand and gravels can be excavated by using grab while excavation of hard strata can be performed by using cutter. Another important factor to be considered is the cutting rate of the trench since it is important to give time for bentonite to form what is called "filter cake" membrane at the wall sides-bentonite surface. Excavation either by using a grab (see Photo 2) or a cutter within the same panel is carried out at more than one stage. The width of the grab jaw and the distance that can be excavated directly by the cutter is limited. The grab or cutter can excavate a maximum of 2.08 meter wide vertical strip, so that a panel of about 6.06 meter long can be excavated by three stages. As a first step in the excavation procedure of any diaphragm wall, guide walls must be constructed in order to prevent any collapse of soil from the top of the proposed wall and also to facilitate the implementation of bentonite pipes which will provide the trench with the bentonite during the excavation procedure (see Fig. 1). During excavation bentonite has to be provided simultaneously to the trench while excavated materials mixed with bentonite are pumped out again to be sent to the bentonite plant for recycling. After finishing the excavation, rock quality test must be performed as the last stage of

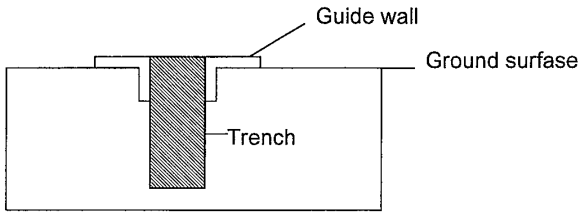

Fig. 1 Location of guide walls.

the excavation since it is desired and recommended to found this kind of walls on hard, fresh and unweathered rocks if possible[2]. If the required rock quality is achieved recycling of working bentonite in the excavated panel will immediately take place for a period of time until getting the required bentonite specification before concreting. This can be achieved with a bentonite sample taken from the bottom of the trench after a complete recycling and it will be tested in order to estimate its sand content, pH, and filter loss and gel strength. This step is followed by checking the depth of the trench by using a long steel rod installed vertically in the trench. Bentonite density just before concreting must not exceed 1.15 gm/cm^3 and its viscosity must be less than 20 cP. This is considered to be very important to ensure enough cleaning of steel bars during concreting and displacement of bentonite. During the process of excavation so many problems take place, these problems and some practical solutions can be summarized in the following paragraph.

1) Verticality of excavation

Excavated trench must be vertical as much as possible within an allowable vertical deviation of about 1%. The solution of this problem was solved by sliding the grab or cutter into and out of the trench and skipping the inside wall sides.

2) Presence of big, hard and smooth surface boulders and stones that keep rolling under cutter wheels or stacking of these stones between the teeth of the cutter.

This problem was solved by crushing the boulders and stones by using heavy chisels, and so crushed materials will be suspended by bentonite and pumped out of the trench.

3) Caving of soil under guide walls

Eventually caving occurs in the portion beneath the guide walls due to the falling of bentonite slurry from the top of the guide walls during the supplying of bentonite. This problem was solved by connecting bentonite pipes with another flexible pipes and lowering these flexible pipes down the trench so as to decrease the falling head of bentonite slurry.

4) Trench collapsing

During excavations in the fill areas, soil tends to loose its strength by absorbing water or by the vibrations caused by the excavating machines. The solution of this problem was achieved by filling the trench and the resulting cavings with low strength sand cement mortar in order to stabilize loose fill bands. After consolidation of mortar, the cavities in the trench sides kept filled with by stable materials. If wanted, the stability of diaphragm wall during excavation can be increased by using temporary vertical tie-down anchors.

5) Bentonite sedimentation

When the time between bentonite recycling and concreting is relatively long, bentonite may precipitate in the bottom of the trench. At this moment, to keep bentonite slurry more homogenous and to decrease its sedimentation rate, dispersing agents or some other chemical materials are added.

6) Soil collapsing during concreting

The soil is expected to collapse at any time during concreting of the wall. However, if any collapse occurred during concreting, the contaminated concrete must be removed immediately. To perform this job, theoretical volume of the trench is calculated before concreting and depth against theoretical volume is plotted on millimetric

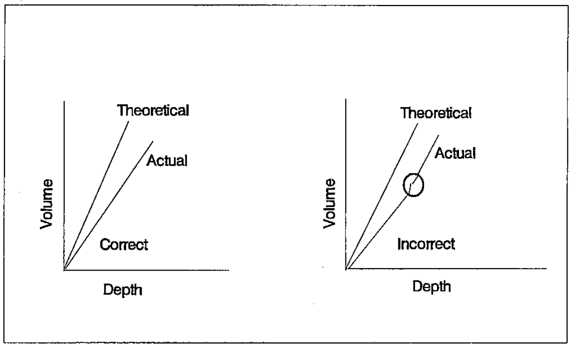

Fig. 2 Detection of soil collapsing during concreting.

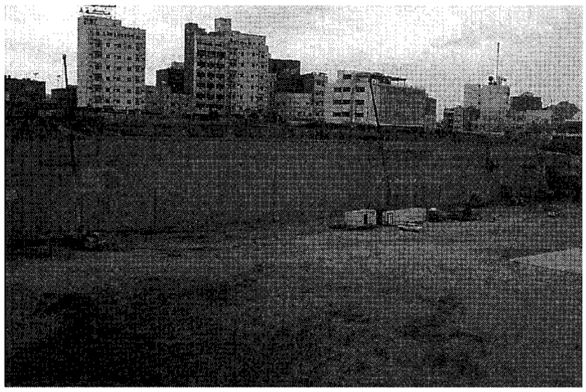

Photo 3 Diaphragm wall after construction.

paper. Continuous recording of depth against actual volume of poured concrete is plotted on the same millimetric paper as shown in Fig. 2. By monitoring this graph soil collapsing can be detected and so concreting must be continued until soil contaminated concrete is taken out.

4. Conclusion

Since there are a lot of applications of diaphragm walls, it is very important to understand the procedure of excavation and its effect on the final structure. Even though the technical problems involved in excavation are plenty, it can be solved by careful study of the land conditions and the study of the case histories available.

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