Fermilab

POSSIBLE APPLICATION OF SLURRY WALL TECHNIQUE FOR CONSTRUCTION OF COLLIDING BEAM EXPERIMENTAL AREAS

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I. Introduction

It is planned to design and start construction of two colliding beam experimental areas on the main ring in the Fiscal Year 1981, starting October 1, 1980. One area will be built at the B0 long straight section, and the other most likely will be at the D0 long straight section.

Each colliding beam area consists of a collision hall, an assembly hall, and a support building. The collision hall is an underground structure, with the floor level roughly 42 ft. below the grade level. The inside width is 45 ft., and the length is roughly 120 ft.

In Fiscal Year 1981, we would like to build the main structure of the collision halls. There will be a shutdown of four and one half months during the summer of 1981. During that time, we have to build the main structure and reinstall the main ring, ready for operation. Out of four and one half months, one month will be allocated for the restoration of the main ring parts. Therefore, leaving only three and one half months for construction.

In our preliminary studies, we have tried to make schedules to meet these constraints, assuming conventional construction methods will be used, namely excavating large areas. To excavate large areas, sheet piling would be necessary, as well as back filling, increasing the time of construction. It has turned out that it is not easy to meet this schedule without a lot of incentives and overtime.

We have learned of a relatively new construction technique, called the slurry wall method (also called the diaphragm wall), which has been applied to many underground structures relating to high rise buildings in downtown Chicago. This technique was used there mainly because the ground is soft, and they could not excavate deeply without affecting the nearby tall buildings. Using this method, walls could be built even while the main ring is running. This cuts down the necessary shutdown time for construction. Thus the whole construction could more easily be done in the specified time.

The following describes the slurry wall method: its merits and associated problems.

II. Slurry Walls for Underground Structures

The use of slurry walls as a solution to construction problems has increased greatly in the past 20 years.[1,2,3] The technique was originated in Europe shortly after World War II and has since spread world wide. At first the technique was considered very specialized, and very few contractors were able to do slurry wall construction. Popularity of slurry walls has increased the number of foundation contractors who are able to build using the slurry technique, although the market is still dominated by the earlier more established contractors. The increased popularity of slurry walls has made the market much more competitive than it once was.

The slurry wall technique is still a relatively new and innovative method of below-ground construction. The slurry wall system is very versatile and has been used in a number of varied projects where ground conditions have been very good, as well as difficult.

The construction of slurry walls is actually a very simple process, in principle, when the soil and ground water conditions are favorable. The steps are as follows:

1. Digging a trench as long as one wall panel to a depth of 3 to 5 ft. which is lined with reinforced concrete guide walls, 8 to 12 in. thick and spaced approximately 2 in. more than the required thickness of the slurry wall. The trench is filled with a bentonite slurry.
2. Bentonite arrives at the construction site in a bulk, dry powdered form where it is mixed with fresh water to form the slurry. Bentonite when mixed with fresh water swells to seal and stabilize the soil around it creating an impervious wall which stops further seepage of ground water. The water also produces a viscosity that suspends pollutants for removal when the slurry is pumped off.
3. The trench for the slurry wall is next excavated with special digging buckets. During the excavation the trench is continually kept filled with slurry to stabilize and seal the soil around it. The excavation is done in different panel lengths according to soil conditions and the equipment used, usually 5 to 10 ft.
4. If a reinforced concrete wall is necessary, a prefabricated reinforcement cage is lowered into the trench through the slurry. The reinforcement cages are the same length as the panels that are excavated.

The construction joints at the ends of the panels are formed by a greased end pipe or wide flange steel beam which can also serve as reinforcement for the wall.

5. The concrete is placed by the tremie method (or pumped) into the trench, and the slurry is pumped off to be used for the next panel.
6. The concrete will cure in the ground and take on the form of the soil around it. If end pipes are used at joints, they will be removed before concrete sets.
7. The interior of the wall structure is excavated, and if necessary, will be tied back by rock anchors or ties grouted into very stable soil.

If necessary, piles can be driven through the slurry for extra wall support. Ducts or other openings can also be cast into the panels by providing spacers in the reinforcement cage which will prevent the concrete from flowing into that area. Conceptual steps are shown in diagram at end of paper.

The engineering design of a slurry wall rests not only in the soil conditions but also in the lateral pressures and how they are distributed. A soil pressure diagram must be developed by a qualified soils engineer who is able to consider the different types of soil and amount of ground-water present at the site. Using the pressure diagram, the engineer is able to design the wall (thickness, reinforcing cage, etc.) in relation to the excavation and installation methods used by the contractor.

Generally, the ground-water level has the greatest influence on the stability of the trench during excavation. The slurry, therefore, must be kept at the proper level in the trench. The bentonite forms a sealing filter cake on the walls of the trench, while the hydrostatic pressure of the slurry is the major stabilizing agent. We do not expect any ground-water problem around the main ring if rains are not unseasonally high.

The most common applications of slurry walls are in underground projects, showing these problems:

1. Very often there is a ground-water problem,
2. Adjacent structures which must not be disturbed during construction,
3. The noise and vibrations from driving sheet piling is not acceptable, and
4. The site is composed of difficult soils.

Slurry wall is very commonly used as a seepage barrier where migration of fresh water or contaminated water could be critical. In this case, the wall may not be exposed but rather remains as a cutoff in the ground.

The slurry wall has also been very successfully used as a basement bearing wall and earth/ground-water retention wall in the Chicago area where the soil around the lake is very difficult. Sears Tower, Water Tower Place, the Standard Oil Building, and the CNA Building are very well known buildings in Chicago that have utilized the slurry wall for their basement structure.

For the Water Tower Place project, the slurry wall was constructed between the perimeter caissons that support the foundation of the building. The Standard Oil Building perimeter slurry walls are supported on H Piles that were driven through the slurry to the base of the trench. No loss in trench stability was noted from the vibrations caused while driving the piles. The wall was further tied into the soil by an anchoring system. The tower at Standard Oil is supported on caissons.

In all projects mentioned above, the slurry walls serve as permanent basement walls and required very little surface treatment. There have been no problems with leakage through joints or elsewhere in the walls.

Slurry walls have been successfully used for other projects: the Humber Bridge in England, the Wolf Creek Dam in Kentucky, several subways throughout the world, and the cities of Chicago and San Francisco sewage treatment centers.

The slurry wall technique causes minimal disruption of the surface, ground movement, construction noise, and vibration; it eliminates underpinning of adjacent structures and provides a cutoff for ground-water permanently as well as during construction. Lastly, recent increased usage has advanced slurry wall technology and created a more competitive construction market.

III. Advantages of Slurry Walls Applied to Collision Hall

1. Necessary shutdown time of the main ring for construction can be shortened because the walls can be made while the main ring is running.
2. Only the area within the slurry walls needs to be excavated. This eliminates the use of sheet piling to hold back existing structures, eliminating damage to the nearby B0 service building.
3. There should not be any major water problems. The slurry walls will be extended approximately 10 to 20 ft. below the floor level into impermeable hard clay, preventing outside water from seeping under the floor. There is also no need for granular fill outside the walls, which collects water, creating hydrostatic pressure in usual construction method. Also, the slurry wall seals off water by its nature.

Granular fill under the floor and small sump pump system inside the wall will most likely be necessary.

4. The overall construction cost is comparable to that of the conventional method for this size construction job. The cost of excavation per cubic yard is higher with the slurry wall method, but the total volume for excavation is reduced. The unit cost of slurry wall is based on the specific method used. The slurry wall technique eliminates other expenditures, including sheet piling, repair to other buildings, perimeter sump pump system, and granular back fill.
5. If necessary, the roof of the collision hall can be made before excavation is begun, increasing construction costs but allowing the main ring to run longer. Otherwise, the roof would be constructed in the conventional method.
6. For a contractor familiar with the construction methods for slurry walls, the construction phase may be simplified.

IV. Problems to be Considered

1. Joint at floor and walls. The floor could be tied to the walls, if necessary, but probably the floor will be a floating slab. The walls will bear the weight of the ceiling and the berm, which weigh approximately 6,000 short tons. The floor will bear the total weight of the detectors, which may be 3,000 to 5,000 tons. Because of this great load, it is best to keep walls and floor independent. As noted above, water leakage at the floor and wall joint should not be a problem.

2. The surface finish may not be smooth, but it may be appreciated as natural as the wooden form finish of the Fermilab High Rise building.
3. The major excavation will take place from inside the slurry walls, causing work to be slower and more costly. The existing tunnel and floor would then be removed in sections. The inside volume is about 10,000 cubic yards. If the rate of excavation is 400 cubic yards/ 8 hours, a minimum of 25 working days is necessary. This work could be done with two shifts, if needed.
4. The wall thickness will be 2 to 3 ft. The floor depth from grade is approximately 42 ft., and the total height of the slurry wall will be approximately 48 ft. The slurry walls at Sears Tower have the total depth of 45 ft. and at the Water Tower Building, 44 ft. One method recommended is to use H-beams along the walls, which would be driven into the clay and extend up into the walls to be used as part of the reinforcement system.
5. The extent of the vibrations caused when driving the H-beams should be considered because of its effect on the main ring, which might possibly be running during this phase of the job.

V. Conclusion

It appears that the slurry wall technique could be successfully applied for the construction of the colliding beam experimental areas at Fermilab, both economically and technically. The necessary shutdown time and water problem associated with construction would also be relieved. If this method should be adopted, a complete engineering study would be performed to eliminate any assumptions and estimations.

Acknowledgment

Dr. S. A. Gill of Soil Testing Service, Northbrook, Illinois, for his instructive discussions.

References

1. Gill, Safadar A., F. ASCE, Applications of Slurry Walls in Civil Engineering, Journal of the Construction Division, ASCE, Vol. 106, No. C02, Proc. Paper 15479, June 1980, pp. 155-167.

2. Slurry Wall Technique used for Health Sciences Building, Concrete Construction Magazine, January 1977.

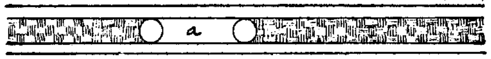
3. Kevin L. Nash, ASCE, Diaphragm Wall Construction Techniques, Journal of Construction Division, Proceedings of ASCE, Vol. 100, No. C04, December 1974, pp. 605-620.

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

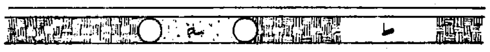
PROCESS OF EXCAVATION

1 

EXCAVATE ONE PANEL

2 

PUT IN PILING AT ENDS OF PANEL TO FORM CONSTRUCTION JOINT. TREMIE CONCRETE INTO PANEL AFTER REINFORCMENT CAGE HAS BEEN LOWERED INTO PLACE.

3 

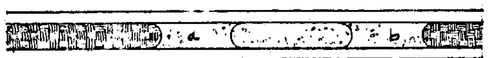
REMOVE PILES (IF NOT BEING USED TO AID REINFORCEMENT) AND EXCAVATE NEXT PANEL IN LEAP-FROG FASHION.

4 

REPEAT STEP 2 AT LOCATION b

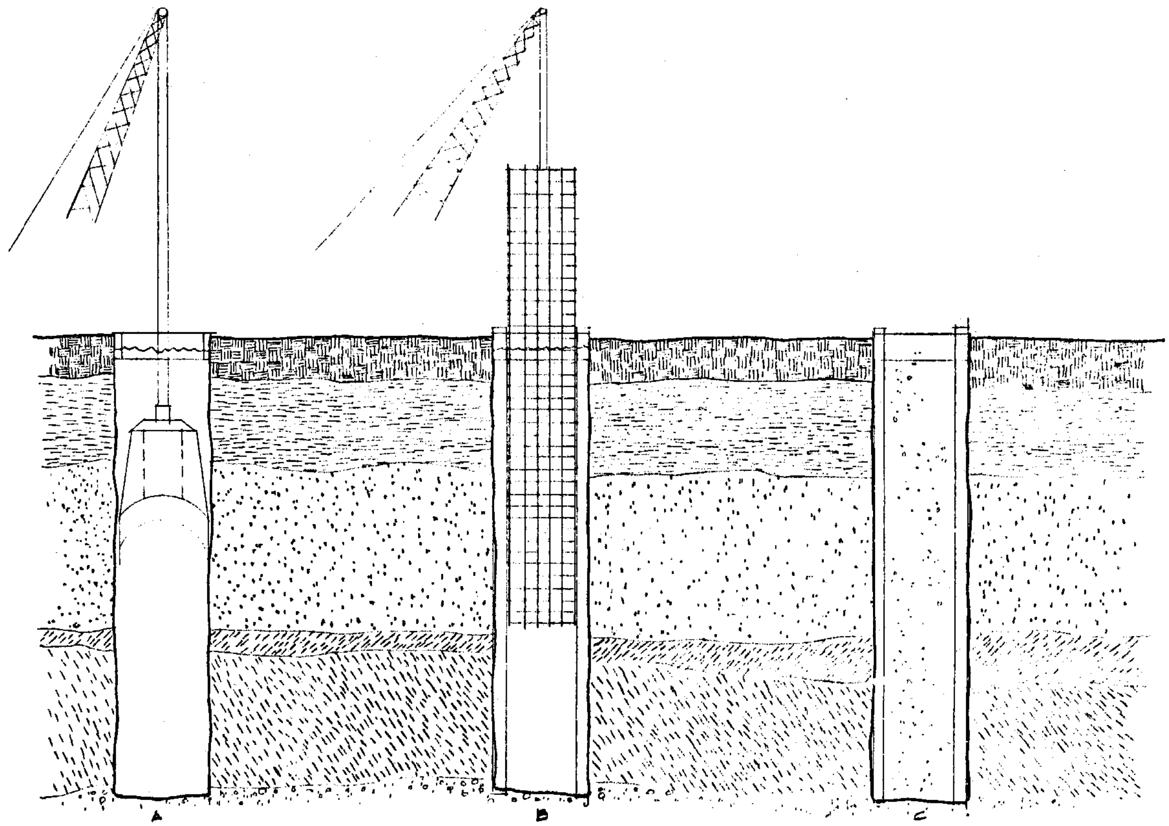
5 

EXCAVATE BETWEEN LOCATIONS a AND b

6 

LOWER REINFORCMENT CAGE INTO PLACE AND TREMIE CONCRETE INTO PANEL — CONSTRUCTION JOINT IS CREATED BY ENDS OF a AND b

EXCAVATION IS DONE BETWEEN TWO CONCRETE GUIDE WALLS SPACED APPROX. 2" WIDER THAN REQUIRED WIDTH OF WALLS. AT ALL TIMES THE TRENCH MUST BE KEPT FULL OF SLURRY TO STABILIZE AND SEAL THE WALLS WHICH FORM THE TRENCH. SLURRY IS DRAWN OUT OF TRENCH AS CONCRETE IS TREMIED IN.



A – EXCAVATE BETWEEN GUIDE WALLS TO DESIRED DEPTH OF SLURRY WALL.

B – LOWER REINFORCEMENT CAGE THROUGH SLURRY INTO PLACE.

C – PUMP OFF SLURRY AS CONCRETE IS TREMIED INTO TRENCH TO FORM FINISHED SLURRY WALL.

– PILES ARE USED AT THE ENDS OF EACH PANEL TO FORM CONSTRUCTION JOINTS. PILES ARE REMOVED BEFORE CONCRETE HAS SET IF NOT REQUIRED FOR REINFORCEMENT IN THE FINISHED WALL.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED					
FRACTIONS	DECIMALS	ANGLES	ORIGINATOR		
±	±	±	DRAWN	B. Welmore	21 July 82
1. BREAK ALL SHARP EDGES 1/64 MAX. 2. DO NOT SCALE DWG. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's. √ MAX. ALL MACHINED SURFACES			CHECKED		
			APPROVED		
			USED ON		
			MATERIAL-		

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SLURRY WALL METHOD

SCALE	FILMED	DRAWING NUMBER	REV.
NONE			