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Durability of Precast Concrete Underground Containers

Durabilité de réservoirs souterrains préfabriqués en béton armé

Dauerhaftigkeit vorgefertigter erdversenkter Behälter

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SUMMARY

This paper describes a segmental construction method for small waterproof reinforced concrete underground containers. Special aspects involving durability of such structures are discussed and highlighted.

RÉSUMÉ

L'article décrit une méthode de préfabrication de réservoirs souterrains en béton armé imperméable. Des aspects spéciaux quant à la durabilité de ces structures sont exposés.

ZUSAMMENFASSUNG

Die vorliegende Veröffentlichung berichtet über ein Konstruktionsverfahren für kleinere, erdversenkte, wasserdichte Stahlbetonbehälter. Besondere Aspekte der Dauerhaftigkeit derartiger Bauten werden besprochen.

1. INTRODUCTION

Waterproof reinforced concrete underground containers are usually constructed by supporting the sides of excavation and concreting the container structure in-situ. For small container structures built to a depth of, say 6 metres, the cost of supporting the soil can be high, which may in certain cases be equal to the cost of the structure itself. Alternatively, if the site conditions allow, sheet piling or other forms of soil supports can be conveniently avoided by using open cut with appropriate side slopes. Nevertheless, this may fall foul of the safety regulations[1] and under heavy rains and wet conditions can lead to slope failure, causing hazard to human lives[2].

A precast cum cast-in-place method was developed to construct an underground container (14.4 m long x 3.7 m x 3.85 m deep) in an open cut in stiff clay[3]. The second year civil engineering students of Nanyang Technological Institute completed the construction of the container in an eight-week period. The work was carried out in two phases. In the first phase, 2.35 m deep precast segments with waterbars fixed to appropriate edges, were placed in the open cut at certain spacings (Fig. 1). These spacings were later filled with cast-in-place concrete. These precast units, in fact sheltered the "student workers" against any probable soil failure during very wet conditions. In the second phase, the structure was completed by finishing the upper 1.5 m of the structure with cast-in-place concrete.

This method of construction, created considerable amount of horizontal and vertical joints. These joints, unless properly detailed and constructed, may, during the service life of the container, lead to overall deterioration of the structure.

In this paper, details of the joints, selection of materials, quality control during construction and future monitoring of the performance of the joints are highlighted and discussed.

2. DETERIORATION OF UNDERGROUND CONCRETE CONTAINERS

Concrete is extensively used in the construction of underground containers. The subsoil and ground water environment can cause substantial damages to these structures during their service life due to interaction of aggressive elements like chlorides, sulphates and acids[4,5]. In such adverse exposure conditions, successful performance of underground structures depends mainly on their durability rather than on strength. Aggressivity of underground environment depends on the concentration of detrimental substances. Main characteristics of corrosive subsoils are low carbonic acid content, high degree of acidity, good conductivity and high salt and moisture content.

2.1 Deterioration of Cement Matrix

In concrete structures which remains permanently below ground water table, the deterioration processes are predominantly of the chemical type. For structures partially submerged, in the zone where groundwater level fluctuates, the chemical actions are augmented by alternate cycles of drying and wetting and other physical agents. Fluctuating ground water table can dissolve the calcium or magnesium sulphates that may be present in the subsoil and deposit them along the concrete surfaces. The sulphate action along with acid and microbial attack brings about a gradual concrete deterioration.

2.2 Deterioration of Reinforcing Steel

If the underground structure is exposed to saline groundwater conditions, the cement matrix is not much harmed, but the reinforcing steel can rust drastically. Rust causes large internal expansive forces which are sufficient to crack and eventually spall off the concret over the reinforcement. This type of damage, if allowed to proceed unchecked, can raise serious questions concerning performance, safety and reliability of the structure. If a decision is taken to repair the damage, the cost could be as high as 10% of the actual cost of the structure.

2.2.1 Corrosion of Reinforcing Steel at Joints

Joints of underground containers can be identified as causing great hazards to the reinforcement. If the joints open up at any time during the service life of the structure, mere penetration of moisture or water can contribute to the corrosion process of the reinforcing steel. This situation can also impair the water tightness of the structure and the structure may be considered as damaged and measures should be taken leading to repairs.

3. CONSTRUCTION OF A PRECAST CONCRETE UNDERGROUND CONTAINER

As mentioned earlier, an underground container was constructed on the Nanyang Technological Institute campus. It is intended to be used for the purpose of geotechnical testing. This container is meant to be waterproof.

In the first phase, 2.35 m high precast segments with waterbars fixed to appropriate edges, were placed on a prepared bed on the open cut at certain spacings (Fig. 2). The precast units in fact sheltered the "student workers" against any soil failure during wet condition. The spaces between the precast units were later filled with cast-in-place concrete. In the second phase, the structure was completed with cast-in-place concrete. The sequence of construction is illustrated in Fig. 1. Two types of precast elements, namely the end units and the internal units, were used. The precast units were cast on a yard near the open cut. A 90-ton capacity crane was used for handling and placing these units. After the completion of the first phase of concreting, the structure was backfilled by granular soil up to 300 mm below the top of this partly constructed container. This facilitated fixing of formwork for the second phase cast-in-place concreting of the rest of the container.

4. JOINTS AND THEIR TREATMENT

Laboratory tests confirmed that the soil surrounding the container are free from sulphates and other aggressive elements. As such, the main concern related to durability as well as watertightness of the container, was treatment of the joints. The reinforcement has to be adequately protected at the joints, because any easy passage of water through these joints, in course of the service life of the container, would cause severe rusting of the reinforcement leading to damage of the structure. Water bars were fixed at all joints of precast elements facing cast-in-place concrete (Figs. 2 & 3). The mix design was carefully specified with the emphasis being on a suitable water-cement ratio, optimum cement content along with workability consideration[6]; hence, during compaction, the water bars were reasonably secured at their positions. To provide further lines of defence against ground water penetration into the container, bituminous coating underlying a polymeric membrane was placed all over the external surface of the container. All bolt holes were plugged with non-shrink cementitious material.

5. MONITORING PERFORMANCE OF THE UNDERGROND CONTAINER

As the container, under service conditions, will be subjected to a surcharge of 20 kN per sq m and various other loads, there is a possibility of differential settlements leading to joint movement. Any deterioration of the joints will be visually monitored and investigated.

6. CONCLUSION

Durability is one of the main criteria in the construction of underground concrete structures. The precast cum cast-in-place method, wherever applicable, is safer, faster and more economical than the conventional cast-in-place method. Also, the problem of deterioration of precast joints does not exist. However, the horizontal and vertical joints can cause durability problems for the structure. Suitably placed water bars at the joints, enhanced by a properly applied bituminous coating underlying a polymeric membrane will definitely help to achieve a satisfactory long term performance of the underground concrete container.

7. ACKNOWLEGEMENTS

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REFERENCES

1. Republic of Singapore, Government Gazette, 1985.

2. The Institution of Structural Engineers, Proceeding of the Symposium on Design and Construction of Deep Basements, Ed: R.J.R. HANCOCK, May, 1981.

3. Nanyang Technological Institute, Information Manual for Students and Project Document, for the construction of a CSE Experiment Station - a sheltered trench for geotechnical testing. In House Practical Training Programme, School of Civil and Structural Engineering, March, 1988.

4. DORAN, S.R., ROBERY, P, ONG, H and ROBINSON, S.A. Corrosion Protection To Buried Structures. Proc. MRT Conference, Singapore, April 1987, pp. 215-224.

5. HARRISON, W.H., Durability of Concrete Structures in Acidic Soils and Waters. Journal of the Concrete Society, London, February 1987, pp. 18-24.

6. BRITISH STANDARD BS 8110: Structural use of concrete, Part 1 - Code of practice for design and construction, 1985.

SEQUENCE OF CONSTRUCTION FOR THE TRENCH

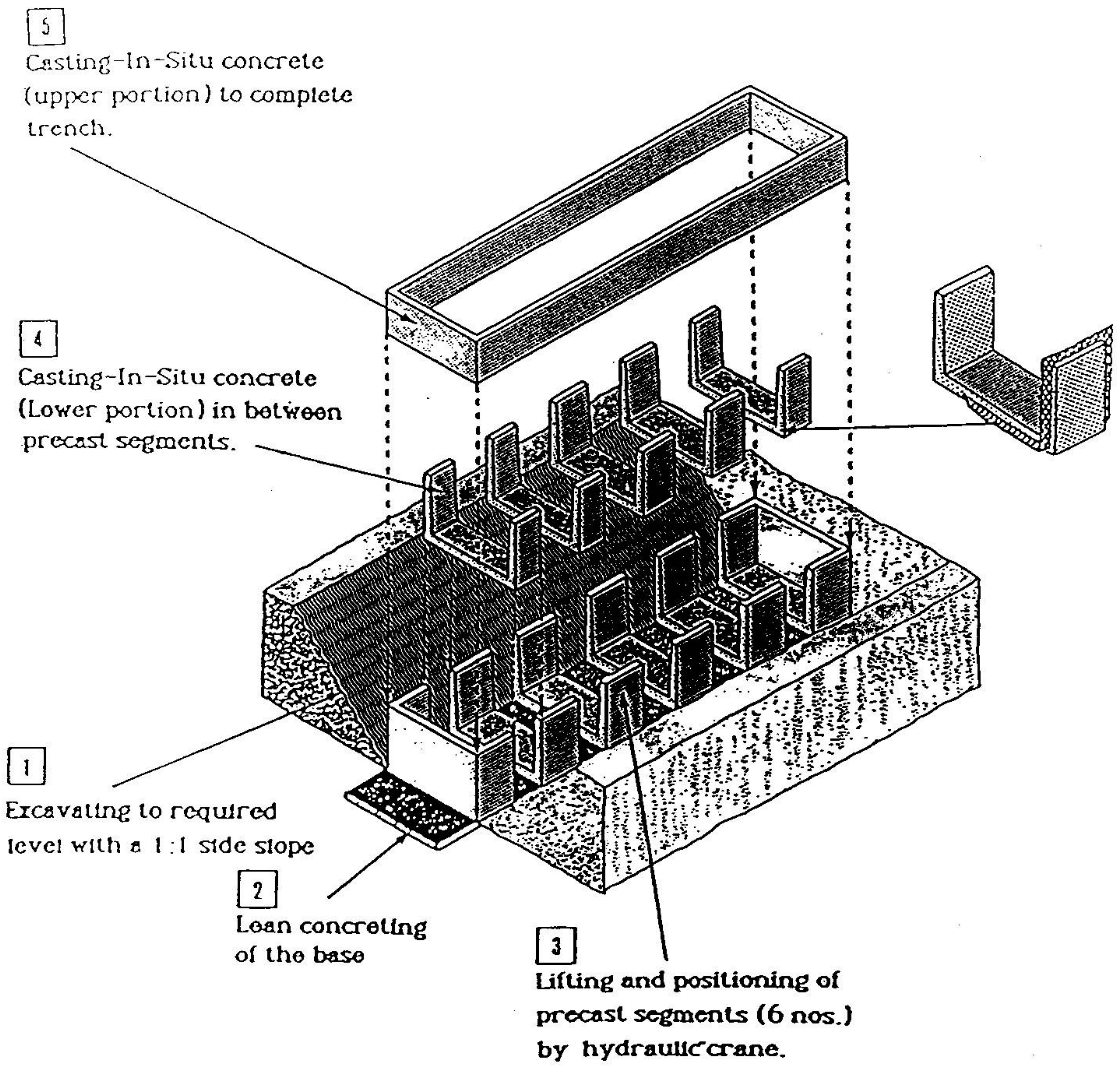

Fig.1 Sequence of construction

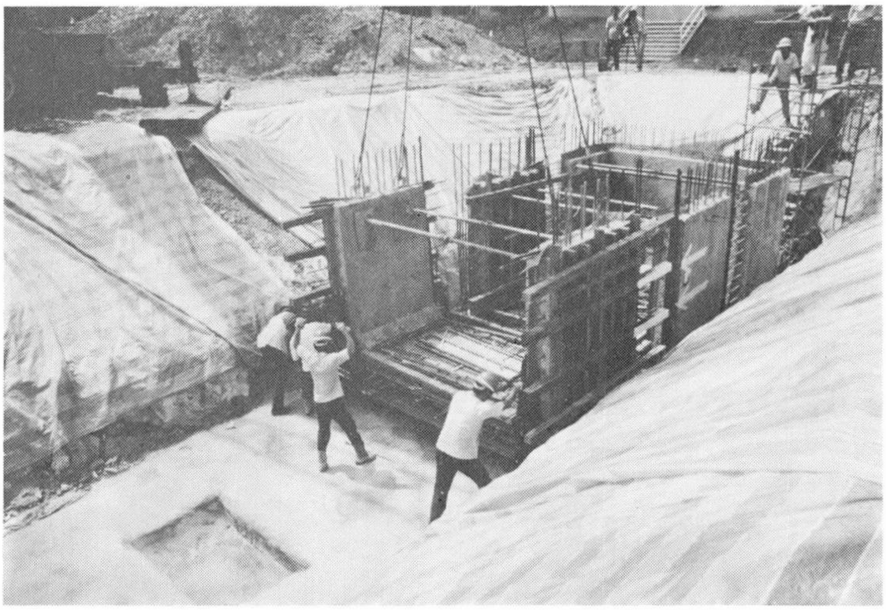

Fig. 2 Precast segments being placed on a prepared bed on the open cut at certain spacing.

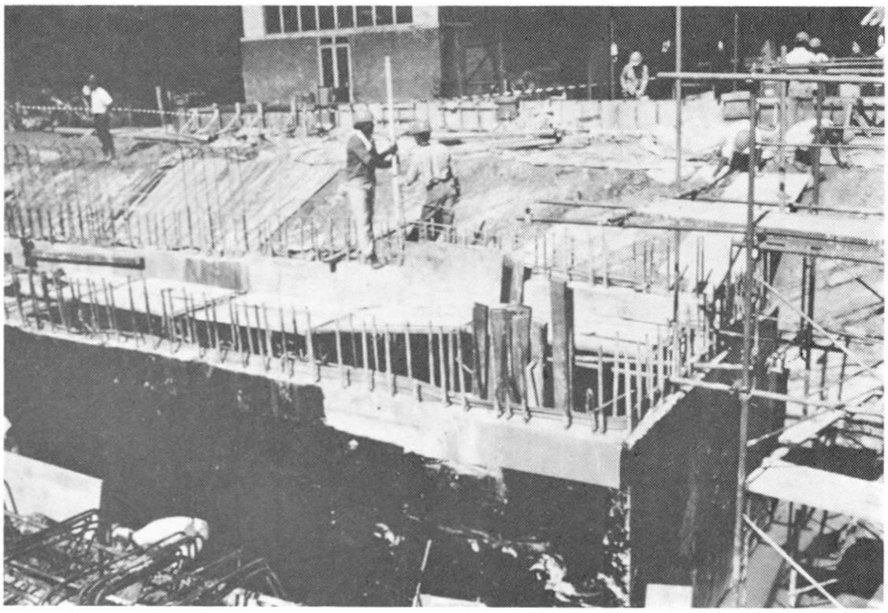

Fig. 3 End of Phase I.
Water bars have been fixed at joints facing Phase II cast-in-place concrete.