REMEDIAL WORKS TO 300,000 GAL. WATER TANK AT BIYAGAMA

by
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Greater Colombo Economic Commission requested CECB to investigate and provide Consultancy Services for remedial works to the 300,000 gal. water tank at Biyagama Investment Promotion Zone, the cylindrical tower of which had developed a horizontal crack around the periphery. The article describes the investigations made to determine cause of failure, the remedial action proposed and implemented for the successful restoration of the tank.

General Description of the Water Tank

The water tower consists of an Intze-type tank, supported by a cylindrical shaft as shown in Fig. 1. This shaft has a 150 mm thick, 10 m high cylindrical shaft of 10.1 m mean diameter. The reinforcement in the shaft consists of 10 mm Tor Steel bars at 225 mm centres both in the vertical and horizontal directions at the mid plane of the wall. Access stairs and pipes are accommodated within this shaft.

The footing of the cylindrical shaft is an eccentric annular ring, resting on the laterite below the ground level. The bearing pressure adopted for the design of the footing is 160 N/m² (1.5 T/ft²).

The tank has a capacity of 1425 m³ and the whole structure is 21.87 m high above the ground. Tank is a typical Intze-type water tank that comprises of a combination of spherical and conical shells, cylindrical side wall and a conical roof joined together by ring beams. A central shaft of diameter 1.5 m has been incorporated in the tank for inspection. The concrete in the foundation and shaft is 1:2:4 and in the tank 1:1 1/2:3.

The Problem

A crack of width approximately 1.0-1.5mm was observed at a height of 5 m from the ground extending horizontally round the shaft approximately from one end of a diameter to the other. It has been reported that during the slipform operation, the zone where the crack has appeared, the concrete was poorly compacted due to a power failure during construction. This crack has been stated to have

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occurred during the first filling of the tank.

It has been checked and there appears to be no deficiency in the design of the footing. The stresses induced in the bottom of the shaft do not exceed 5 N/m^2 (725 lb/in^2) and are considered to be well within the permissible safe limit for concrete with a design strength of 20 N/mm^2.

10 mm rebars have been provided in the annuals of the shaft at 225 mm both vertically and horizontally at the mid surface of the circular stiening. If the shaft is considered to be a reinforced concrete wall, it must have been provided with a minimum of 0.4% of steel, whereas only 0.23% have been provided (Ref. Clause 3.11.4.1 of CP 110).

Schmidt Hammer test results indicate that low values of these results are concentrated along the crack. However, some low values have also been observed over different isolated zones, suggesting that weaker zones of concrete could be scattered over the surface.

Some core samples were obtained from the concrete laid in the shaft and were tested by the National Building Research Organization. The results show the strength of concrete varying from 9.2 N/mm^2 to 12.72 N/mm^2.

A review of these findings shows that

i) The reinforcement in the shaft is less than the minimum specified in the code for a reinforced concrete structure like this.
ii) The concrete strength is in the range of 9.2 N/mm^2 to 12.72 N/mm^2 against the nominal specified strength of 20 N/mm^2.
iii) Evidence of deficiency of construction exists both in zone of the crack (reported to be due to a power failure) and elsewhere the concrete is of varying sub-standard quality, which could be due to a variety of factors like segregation of aggregates, high W/C ratio and more importantly the quality of cement available in the market which is often suspect. No pre-construction tests of Cement were available to ascertain this.
iv) Assumption of the bearing capacity of the foundations and the design of footing for the shaft appear adequate and no signs of distress have been observed on this account.

It appears that while the occurrence of the crack in the shaft is a manifestation of a known construction constraint, general deficiency exists both in respect of design provision and quality of construction.

Proposal for Remedial Works

In consideration of the factors described above, treatment of selective zones was ruled out and measures to strengthen the shaft as a whole were proposed. Reinforced shotcrete was considered to be an appropriate measure which could be depended upon to act in conjunction with the existing concrete and which had the advantage of ease and expediency of construction. Following sequence of operations was accordingly prescribed keeping the stability of the structure in view during the implementation stages.

1. Chipping of shaft surface both inside and outside.
2. Breaking part of the concrete at the foundation ring beam to expose the reinforcement.
3. Breaking diametrically opposite zones along the major weak zones in patches not exceeding 600 mm x 600 mm and reconcreting them. When concrete of one set of patches was hardened another diametrically opposite set would be taken

up for breaking and reconcreting.

4. Fixing of reinforcement Y10 at 225 mm vertically and R6 at 225 mm horizontally for both inside and outside faces. (Fig. 2)
5. Drilling of holes through shaft to insert the R10 tie bars to be welded to inside and outside reinforcements. These ties were placed at a grid of 0.45 m. sq. (Fig. 2)
6. Grouting the holes drilled for tie bars.
7. Applications of suitable epoxy resin to bond hardened concrete to fresh concrete.
8. Shotcreting the reinforcements to build 75 mm layer in two operations (two layers each of approx. 37.5 mm thick).

In April 1986, State Engineering Corporation commenced the remedial works and completed them within six months. The total cost of repair works has been approximately Rs.670,000.00.

The tank was filled after repairs in the last quarter of 1986 and has been under use since then with satisfactory performance. It may be stated that with proper preparation of the surface of old concrete a dependable bond can be ensured between shotcrete and old concrete for integral action of the composite section. Suitable bonding agents or additives in shotcrete can be used with advantage to improve the bond even further.

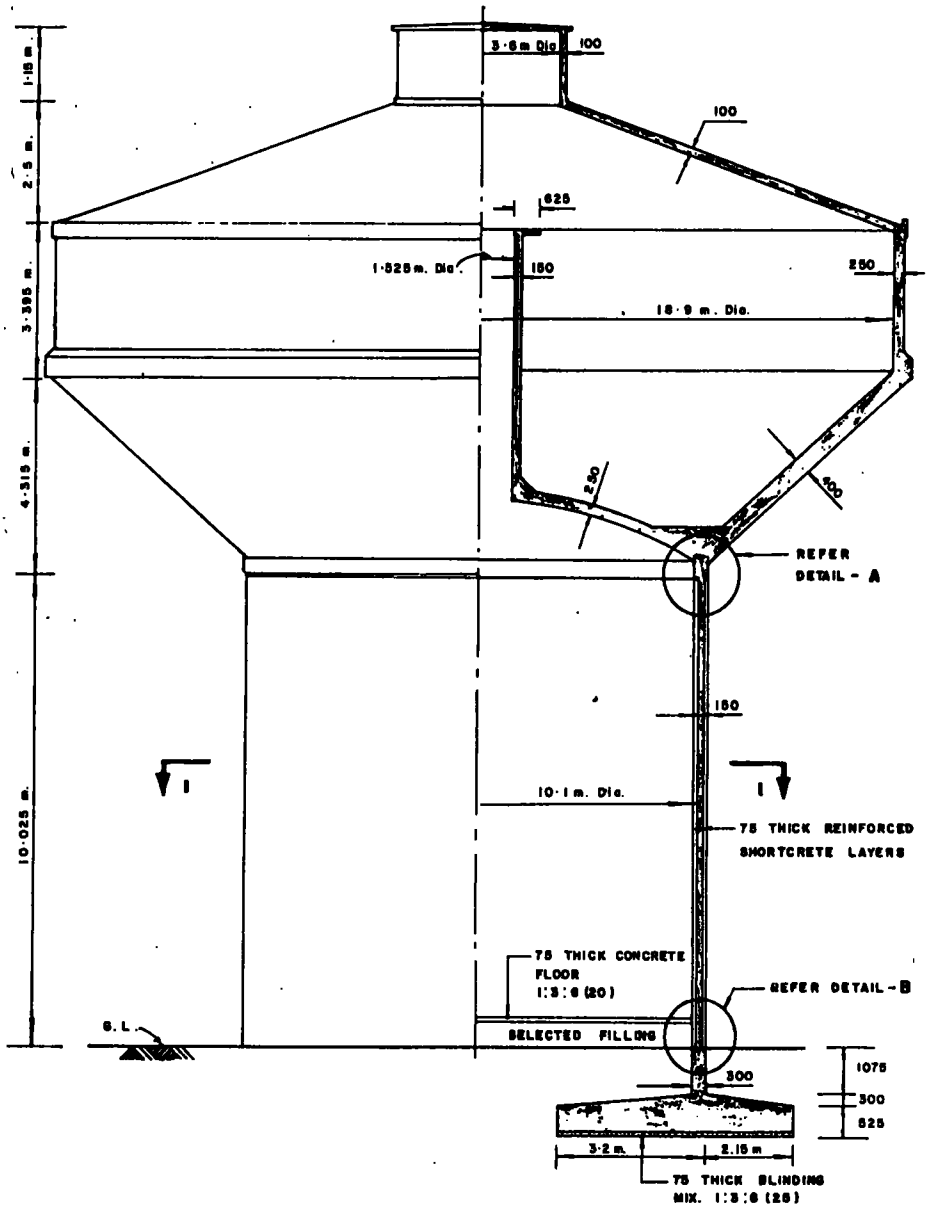
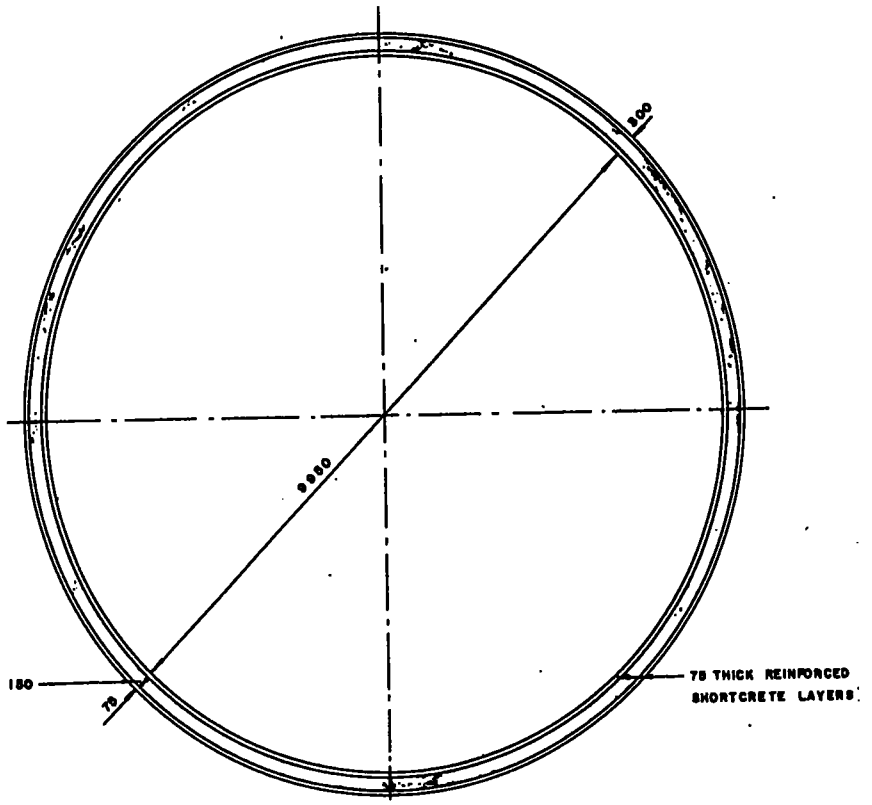
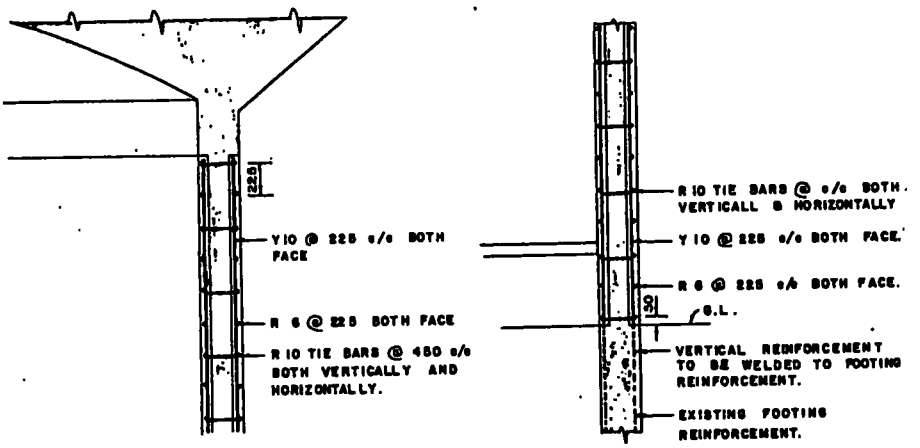


Fig: 1. SECTIONAL ELEVATION
THROUGH VERTICAL CENTRE LINE OF THE TOWER



SECTION I-I



DETAIL- A

DETAIL - B

Fig: 2. ARRANGEMENT OF REINFORCEMENTS