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DEPARTMENT OF MINES
SOUTH AUSTRALIA

REPORT ON INVESTIGATION OF FOUNDATION FAILURE AT E.T.S.A. SUB-STATION LINDEN PARK

LOCATION:

Corner Portrush Road and Sturdee Stree, Linden Park.

SUBMITTED BY:

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Two 24" diameter power-auger boreholes were put down on the site and the following profiles were revealed:-

BORE No 1. (near S.W. corner of building.)

0 - 1'2"	Dark brownish-grey sandy clay loam. Finely granular structure.
1'2" - 3'2"	Khaki-brown clay, granular near top, coarsely granular to prismatic lower. Bright sheen on structural units.
3'2" - 7'3"	Red-brown, slightly sandy clay, with numerous pockets of earthy lime. Clay has bright sheen where there is no lime.

BORE No 2. (near north side of building.)

0 - 8"	Fill material.
8" - 2'9"	Khaki-brown clay, granular near top, coarsely granular to prismatic lower. Bright sheen on structural units.
2'9" - 3'4"	Reddish-brown, slightly sandy, sub-prismatic clay, with scattered lime pockets.
3'4" - 5'0"	Red-brown, coarsely granular clay, with abundant pockets of earthy lime. Clay has moderate sheen where no lime occurs.

The soil is transitional between Type RB3 of the Urrbrae Association and Type BE1 of the Claremont Association.

Seasonal shrinking and swelling movements of large magnitude occur in the clay horizons of this soil, the vertical component of such movement ranging up to 2".

The incidence of foundation failure in brick or masonry houses with ordinary strip footings seated on such soils is high. More than 50% of such houses show some cracking and many are seriously disfigured.

The foundation practice generally recommended for this type of soil is the use of pier and beam type foundations. There are several essentials to a properly constructed pier and beam foundation, the omission of any one of which nullifies the effort put into the remainder of the structure.

These essentials are:-

PIERS:

(a) Should be smooth sided in order to keep the friction between the clay and pier to a minimum.

(b) Should have enlarged bases in order to increase the bearing area and to anchor the pier against uplift forces operating when the clay swells.

(c) Should be seated below the zone of soil moisture variation, usually at a depth of 7 ft below the surface. This is because the clay movement is due to the absorption and yielding of moisture seasonally, therefore a clay with constant moisture content does not shrink and swell and hence provides a stable foundation.

(d) Should have the pier shafts reinforced with steel rods to resist the differential tensile stresses imposed by the swelling clays.

BEAMS:

(a) Should be kept clear of the soil surface by at least the amount of the anticipated vertical soil movement. This is to prevent the swelling clay lifting the beams off the piers. The necessity for this precaution will be appreciated when it is realised that the force exerted by the swelling clay is of the order of 8 tons per square foot.

(b) Should be reinforced with steel rods top and bottom, the bottom reinforcing to help support the weight of the superstructure and the top reinforcement to resist any stresses that might be imposed by movement of the piers.

(c) Should have their reinforcing rods tied in with those of the pier shafts to prevent sideways movement of the piers due to lateral stresses.

This type of foundation construction is obviously not suitable if the building is to have a concrete floor.

An alternative foundation which has been used with success on swelling and shrinking soils, and one to which a concrete floor can be adapted, is the very deep beam.

This consists of a well reinforced beam type foundation 30" to 36" deep and set well down into the soil. It is very necessary to keep the width of such a foundation to a minimum in order to present as small a face as practicable to the uplift forces. Suggested widths are 14" for external walls and 10½" for internal walls. The minimum reinforcement requirements for this type of foundation are 6 x ½" rods (3 top and 3 bottom) for external walls and 4 x ½" rods (2 top and 2 bottom) for internal walls, with 2 extra top reinforcing rods beneath large openings.

The concrete floor should have a base course of coarse road metal about 10" thick, well tamped and topped with a layer of finer screenings. Over this should be laid a bituminous damp course and then the concrete floor. The concrete floor should have a minimum thickness of 3" and be reinforced with steel reinforcing fabric. The selvedge of the floor should have a greater thickness, about 9", and extra reinforcing. The edge of the floor should be separated from the foundation beams by a ½" bitumastic seal completely around its perimeter.

A concrete path completely surrounding the building helps to reduce soil moisture variations and thus tends to stabilize the foundation area.

Care should be taken to prevent saturation of the foundation area at all times. Rain run-off, roof drainage and all waste waters should be carried well away from the foundation area in properly constructed drains, otherwise settlement failure is likely to occur. Likewise all gardens and lawns should be kept clear of the foundations in case damage should result from over watering.

The foregoing remarks are intended as a guide to future sub-station designs where difficult foundation soils are involved. It cannot be too strongly stressed however, that examination of the soil profile and identification of its foundation properties is a necessary prerequisite to proper foundation design.

The deficiencies in the foundation design at the Linden Park sub-station should be apparent from the above remarks and some of the causes of failure are thus indicated. The pattern of cracking in the building suggests that some planes of weakness were probably initiated during the 1953 earthquake. However, it is considered that this merely hastened the ultimate failure that was bound to occur due to other and more serious differential stresses imposed on the building. The serious failure that occurred in the whole south-western part of the building is considered to be due to three factors:-

(i) A rainwater drain running along the southern side of the building is inadequate and discharged water onto the ground at the south-western corner of the building.

This saturated the soil in this locality thus causing loss of strength in the soil and consequent settlement.

(ii) A pier on the western side of the building and about mid-way between the southwestern corner and the front porch was gripped by the swelling clay and thrust upward.

(iii) The large concrete slab at the front porch provided a stable point, or fulcrum about which the other two factors acted.

Remedial measures within the bounds of practicability are not likely to be completely successful due to deficiencies in the fundamental design. However, repairs can be carried out and corrective measures can be adopted which should minimise seasonal stresses in the future.

First of all measures should be taken to divert all water away from the south-western corner of the building. This is essential if underpinning is to be successful.

Next the damaged walls should be supported on jacks and carefully jacked back into position, leaving the actual corner of the building and its foundation free. The soil at the corner should then be excavated to a depth of 7 ft and a 3ft x 3 ft slab of reinforced concrete 9" thick laid in the bottom. When this has properly set the pin should be erected to the corner of the building and the excavation filled. A further pin, similarly constructed should then be placed about midway along the southern wall. The excavations made for the jacks should be back filled with concrete. The cracks and damaged mortar should then be gouged out and the cracks repaired. A concrete path, or apron should then be placed over all the exposed soil in the vicinity of the foundations for a minimum width of 5 feet and permanent drains should be constructed to carry all waste water into the street gutter.

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