INVESTIGATION OF STRUCTURAL AND FOUNDATION FAILURES OF THE GODAKAWELA AGRARIAN SERVICES CENTRE BUILDING

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INTRODUCTION

The Agrarian Services Centre Building located at Godakawela in Rathnapura District is a single storey building constructed in 1976. At present, the building is completely abandoned due to propagation of wall cracks [Figure 1(a)], floor deformities [Figure 1 (b)] and wall deflections etc. A close observation indicated that some cracks appearing on the walls continued to the foundation and most of the cracks are wider than 10 mm. Further, it was also observed that there is hardly any system to drain off rain water from the vicinity of the building and in fact rain water accumulates within the premises aggravating the situation.

A cursory observation of the buildings in the surrounding area indicated that similar cracks in walls are common in most of the relatively old single storey buildings. It was suspected that the soil in the area consists of expansive clays.

Expansive soils shrink and swell when the moisture content changes from dry to moist and vice versa. Thus, shrinking and swelling can be reduced if the moisture content is kept stable. Major damage can be avoided if a few precautions are taken to ensure that the soil under the foundation does not experience excessive moisture changes (Thomas, 1998).

(a) Wall cracks (b) Floor deformities

Figure 1: Cracks appearing in the building

METHODOLOGY

It was necessary to verify that the problematic soil present under the foundation of the building is in fact expansive soil. Plasticity index — the difference between liquid limit and plastic limit — is the most commonly used indicator of soil expansive behavior. The Atterberg limits, which include liquid limit (LL), plastic limit (PL), and plasticity index (PI), define moisture content boundaries between states of consistency in soils (Casagrande, 1948). Laboratory tests were conducted to determine Atterberg limits to classify the soil according to

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ASTM D2487. Also, the swell potential of the problematic soil was determined in the laboratory according to the method described in ASTM D 4546-03.

Further, using this as built data, since no construction drawings were available, the contact pressure exerted by the existing foundation of the single storey building was evaluated to compare with the swell pressure of problematic soil.

FIELD INVESTIGATIONS

Soil samples were collected from three test pits located very close to the strip foundation of the building. Pits were dug up to 1.5 m by using minor tools and hand auguring was done on the basis of each test pit to obtain more information on sub soils. Disturbed and undisturbed samples were collected to carry out the laboratory tests.

Subsurface exploration drilling and soil mineralogy tests were not carried out due to the budgetary constraints.

LABORATORY INVESTIGATIONS

Laboratory investigations were carried out at the Soil Laboratory of the Central Engineering Consultancy Bureau (CECB). Following tests were done on the collected samples to determine the required soil parameters.

- Natural water content
- Bulk density test
- Atterberg limits
- Specific gravity test
- Shrinkage limit test
- Swell index test
- Direct shear test

RESULTS AND DISCUSSION

Sub Surface Condition - Findings

Subsurface soil profiles, as described in Table 1, were identified by field and laboratory investigations. The foundation of the building is seated on Layer No. 2.

Table 1: Geotechnical properties of soils (Classified according to ASTM D2487 – 06)

Layer No.	Layer Description	Depth Range (m)	Unit Weight (kN/m^3)	Cohesion (kN/m^2)
1	Fine to coarse grained Clayey Sand (SC)	Ground – 0.85	18.1	10
2	Slightly gravelly Sandy Clay (CH)	0.85 – 1.50	16.5	11 - 14
3	Fine to medium Sandy Clay (CS)	Below 1.50	17.0	11

Results of Laboratory Tests

Results of the Atterberg limits tests conducted on the problematic soil samples collected from Layer 2 are plotted in the Plasticity Chart shown in Figure 2. Figure 2 shows that the LL of problematic soil varies from 44 to 62% and PI varies from 28 to 43%. Based on the classification proposed by Holts & Gibbs (1956), as shown in Table 2, soils having these ranges of LL and PI are classified as soils having “**high”** potential swell. Chen (1975) also classified soils having liquid limit ranging from 40 – 60 as soils with "**high**" potential for expansion. This confirms that the problematic soil found at the site is a soil with a high potential swell.

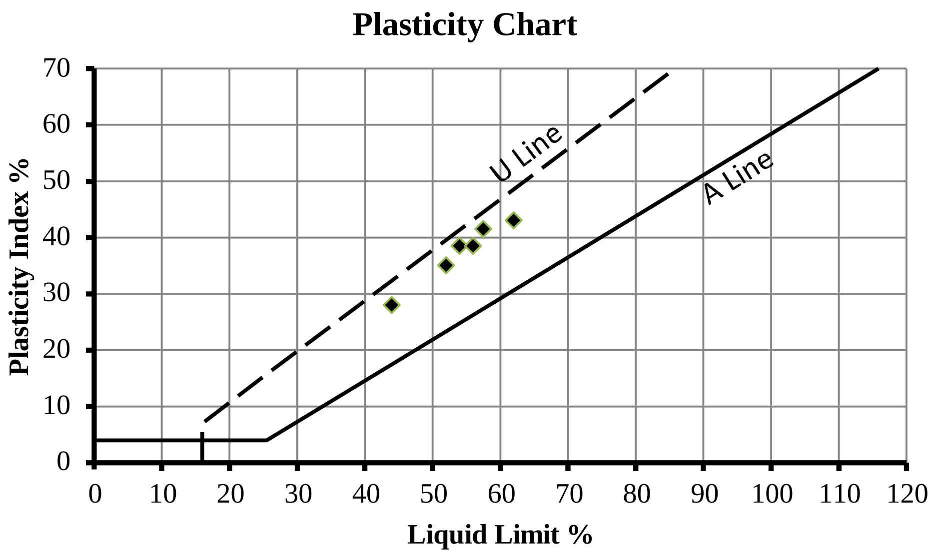

Figure 2: Results of Atterberg limits test on problematic soil

Table 2: Classification of potential swells (Holtz and Gibbs, 1956)

Classification of potential swell	Liquid Limit (LL) %	Plasticity Index (PI) %	Shrinkage Limit (SL) %
Low	20 – 35	< 18	> 15
Medium	35 – 50	15 – 28	10 – 15
High	50 – 70	25 – 41	7 – 12
Very high	> 70	> 35	< 11

Results of swell index test conducted according to the method described in ASTM D4546 – 03 (2003) indicated that the swell index of the problematic soil varies from 41 to 60 kN/m^2.

Single storey Agrarian Services Centre building consists of a Calicut tiled roof, 225 mm thick load bearing brick walls and a rubble masonry foundation. The depth of the foundation observed at site was 0.85 m below ground surface and the width of the rubble masonry foundation was taken as 0.45 m. The contact bearing pressure calculated using the above data is 41 kN/m^2. This is less than the **"swell pressure"** of the tested soil, defined in ASTM D4546 – 03 (2003) as the pressure which prevents the soil from swelling.

CONCLUSION/RECOMMENDATIONS

Seasonal changes in moisture content of soil due to wetting and drying results in substantial expansion and shrinkage in expansive soils. Being a single storey building, the contact pressure on soil exerted by the foundation is not sufficiently large to counter the swell pressure exerted by expansive soils and has resulted in foundation movements thus producing cracks in the walls of the building. Following recommendations can be made to make the abandoned building serviceable:

1. Isolate the strip foundation with a cut off wall (Wray, 1995) – Construct a concrete cut off wall along the pavement of the building to cut off seepage of water reducing the seasonal changes of moisture content of underlying expansive soils. It is advisable

to waterproof the external face of the cut off wall before backfilling.

2. Improve drainage of water in the surrounding area (Wray, 1995) – Reduce infiltration of water adjacent to the building by constructing an impervious surface (concrete surfacing or precast cement sand tiles are recommended) and facilitate drainage of water by having a proper drainage system within the premises in order to avoid saturation due to high seepage during rainy season.
3. Repair the hairline cracks of the wall – Structural integrity of the building is not affected by hairline cracks and by preventing occurrence of seasonal changes in moisture content of underlying expansive clay, re-appearance of these cracks can be prevented.
4. Demolish the walls structurally damaged and re-construct – Where the cracks are very wide and complete separation of wall has occurred, demolish the wall and re-construct it.

Contact pressure exerted by single storey buildings is too small to counter the resulting swell pressure of expansive soil according to the experimental results. If sufficiently large contact pressures are applied, effect of swell pressure can be balanced or minimized. This can be achieved by having high structural loads by constructing at least two storey buildings. However, considering the small thickness and the shallow depth of the expansive soil layer the most economical solution for future constructions would be replacing the expansive soil layer completely with suitable well compacted material.

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