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Foundations of the Indian Museum Building, Calcutta

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Introduction

The Indian Museum building is a majestic brick structure (Fig. 1) located at the finest site of Chowringhee in Calcutta. The foundation of the museum building, earlier known as Imperial Museum, were laid in 1867 and the main building was completed in 1875. W.L. Granville designed the building. Construction of an additional wing was started in 1895 which might have completed by the turn of the century. Thus, the present structures are about 125 to 90 years old in 1990. The Imperial Museum was first started in 1814 in the premises of the Asiatic Society, Calcutta and the 175th anniversary of the museum was celebrated in 1989 (Sharma, 1989).

During the course of about 180 years of eventful history, the museum has amassed a great wealth of artifacts. There has been no addition to the museum building during the last 90 years and on account of shortage of space a large number of important exhibits are simply stored without proper display. The trustees of the Indian Museum were interested in exploring the possibilities for creating more space in the galleries on the eastern, northern and southern sides of the courtyard either by adding mezzanine floors in the display galleries or some suitable alternatives keeping in view the importance of the building as an architectural heritage of Calcutta.

From time to time various organisations have been associated with the upkeep and maintenance of the building. Incidentally no drawings, except a key plan of the site, were available. While superstructure could be easily examined visually and measured, foundation buried underground were

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FIGURE 1 : Indian Museum, Calcutta (Front View from North-West)

unknown. Foundation details were necessary, apart from assessment of the condition of the structure, for any programme of addition of mezzanine floors which would add to the load on foundations. For this information investigations were carried out for ascertaining the type and geometry of foundations and nature of substrata.

The Building

The Indian Museum building is a massive brick structure in Gothic style architecture. There are several other buildings of similar features from the same period in Calcutta. The building plan like the letter P (Fig. 2) the rectangular lawn being the open space. The main wing facing Chowringhee is three storeyed. Large arched openings and verandahs around the central courtyard (Fig. 3) are its prominent features. The ceiling heights are 8.9 m and 15.3 m in the ground floor and first floor respectively. The verandahs around the courtyard have a ceiling height of about 8.9 m in both the floors.

The building consists of load bearing walls and columns (Fig. 4) supporting arches and girders over the openings and for supporting the roof (Figs. 5 and 6). The outer wall is 1.4 m thick. The brick columns of different sizes have been provided. The column size in the display gallery on the eastern side is 76 cm × 76 cm on plinth of 92 cm × 92 cm. The bricks used are of nominal size 10 in × 5 in × 3 in. The brickwork is in lime mortar. The intermediate floor and roof mainly consist of thick RSJ as the main load bearing girders supporting cross T sections laid over with tiles and lime concrete.

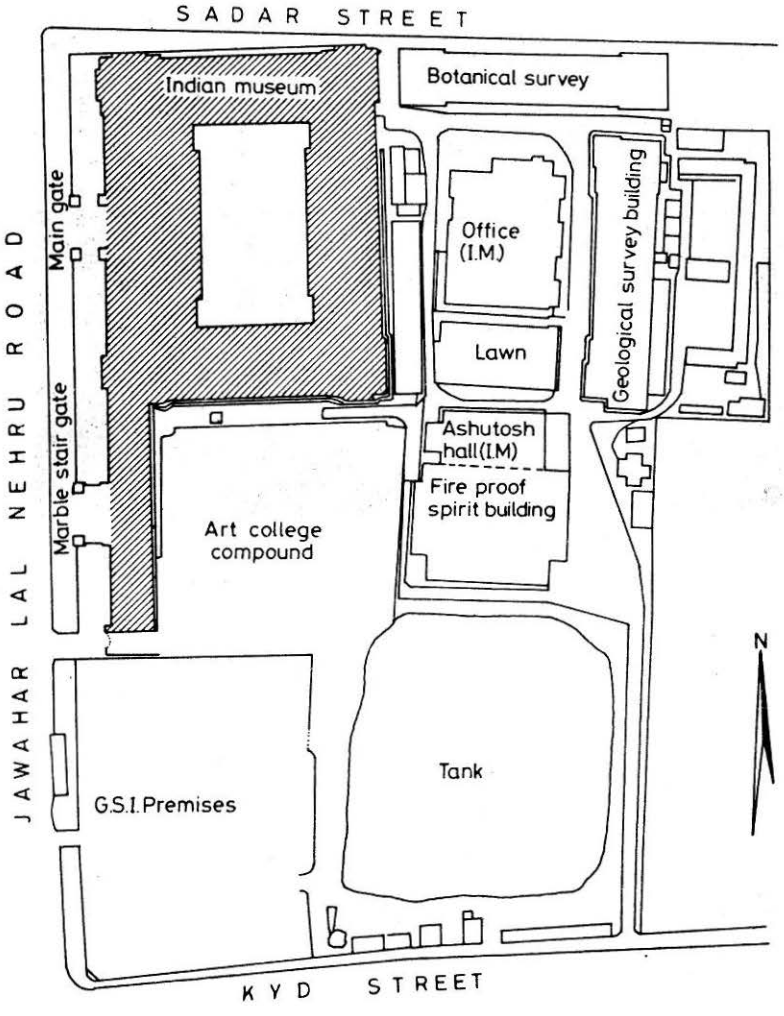

FIGURE 2 : Key Plan

Several cracks could be observed in the walls and the arches may be due to both the deterioration of material and differential settlement. It could be noticed visually in the courtyard that the southeast and southwest corners have sunk down. The front block facing Chowringhee has settled more over the years as compared to the rest of the building as evidenced by vertical cracks wider at top in the walls of north and south blocks (Fig. 7). Loss of adhesion in the mortar, rusting of RSJs and seepage of water from roofs and fittings for sanitary and water supply and consequent adverse effects were also visible at certain locations. On account of repairs from time to time it was not possible to identify all the cracks hidden under plastering

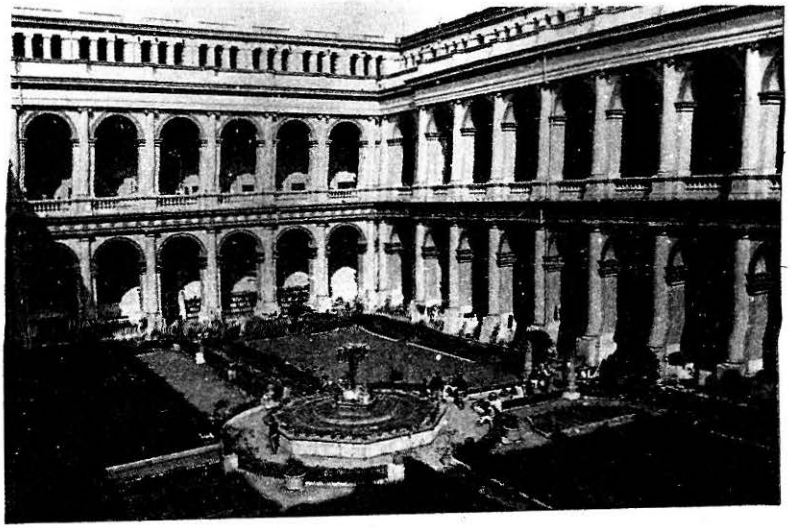

FIGURE 3 : Central Courtyard (South-East Corner)

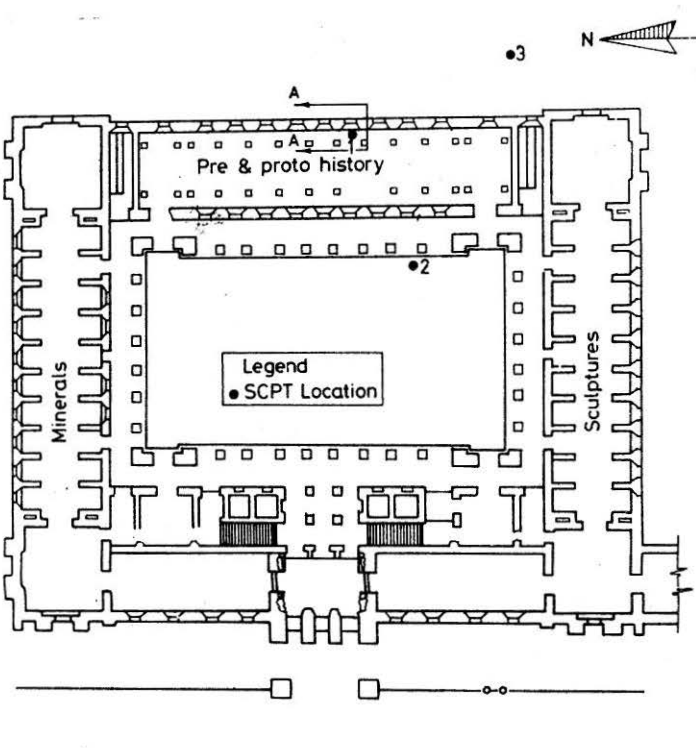

FIGURE 4 : Ground Floor Plan of Main Quadrangle

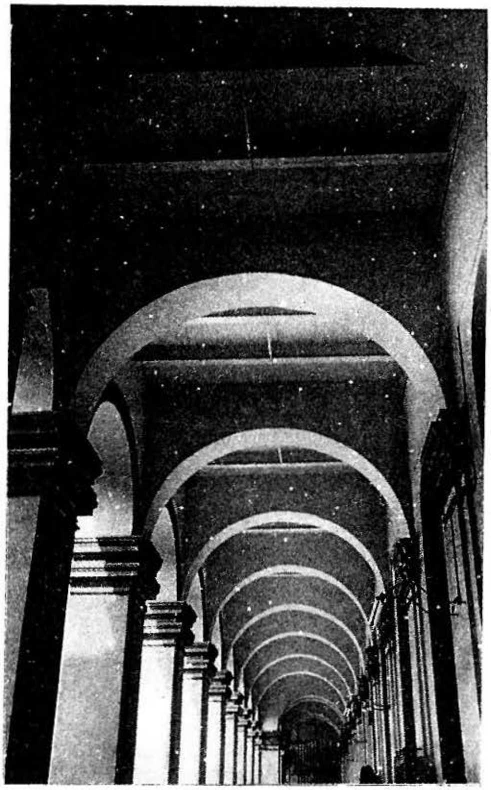

FIGURE 5 : View of Corridor with Arches

and painting on walls, however, reappearance of the cracks at some of the locations of the earlier ones indicate that cracks have been active. Cracks and distortions in some of the arches were quite obvious.

The museum building complex has very limited open space. Incidentally the ground floor gallery on the eastern side had been vacated for repairs and this provided an opportunity for foundation investigations by digging a pit in between the outer wall and the row of the columns (Fig. 4). A static cone penetration test was also carried out adjacent to the pit. Two more static cone penetration tests were carried out in the open courtyard and on south-east behind the building (Fig. 4). Information on soil strata along with standard penetration test carried out by another agency was available from site near the Indian Museum Building.

The details of the foundation confirmed by digging are shown in Fig. 8. The most striking features are their massive nature, great depth and close proximity of 0.56 m clear distance between the two strip footings. The depth

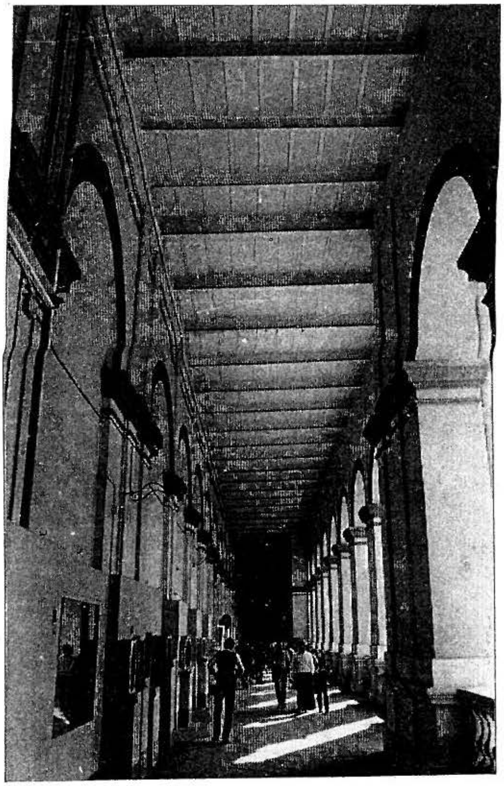

FIGURE 6 : View of Corridor with Steel Section in Ceiling

below the plinth, which is of varying height above the present ground levels, is 3.72 m. It seemed that ground level had been raised above the original level.

The range of variation of resistance for three penetration test curves is shown in Fig. 9. The available strata details from the adjacent site did not show well defined uniform layers; however, a generalised sequence was top fill of clayey silt of 0.5 to 5.0 m thickness followed by sandy and clayey silt of 2 m to 5 m thickness followed by sandy and clayey silt of 2 m to 10 m thickness, followed by clayey silt with decomposed wood 3 m to 6 m thick and below it layers of silty clay with kankar and clayey silt with sand. The thickness variation in layers was rather erratic. The same might be the situation for the building site under reference. The strata as revealed by digging the pit in gallery is shown in Fig. 10. The site of the museum building is flat land. Geologically the strata are alluvial deposits of the Gangetic plains. Occurrence of stratum consisting of decomposed wood is typical of Calcutta deposits (Dastidar and Ghosh, 1984) . It is generally of

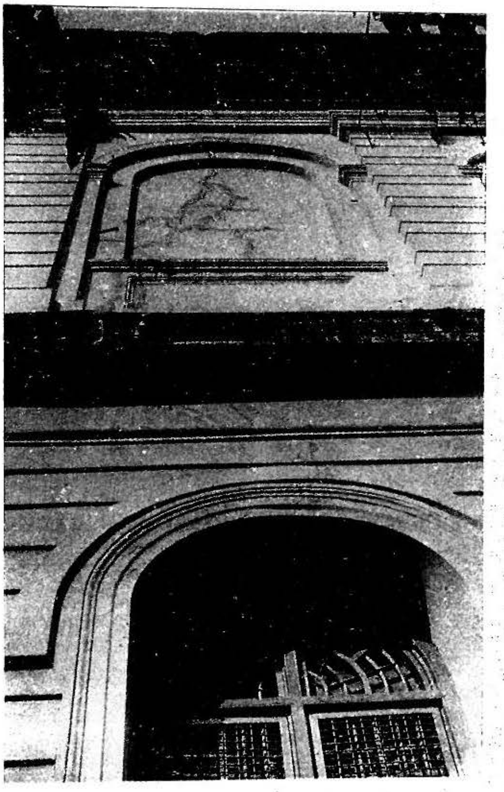

FIGURE 7 : Crack on Southern Side Wall

low 'N' value within 10. This strata corresponds to depths between 10 m to 15 m (Fig. 11) showing very low penetration resistance. Strata between about 5 m to 9 m is of better but erratic resistance. The foundations are resting on this strata of varying resistance.

The general ground slope is towards the Chowringhee. The floor level of the front wing entrance is lower than the remaining rear part. During heavy down-pours in rainy season the steps leading to the entrance get submerged. The surface drainage in the area is not good. During the winter months of 1990 the water level was found at 3.6 m depth below the floor level in the eastern gallery while digging the pit towards the end of rainy season. It was likely to be within a meter below the floor during the years of excessive rains. In present situation a part of the footings depth must be always under water. It is also said that there is a general rise in water table during the past. At the time of construction, 125 years ago it can be reasonably assumed that the strip footing must have not been constructed under water.

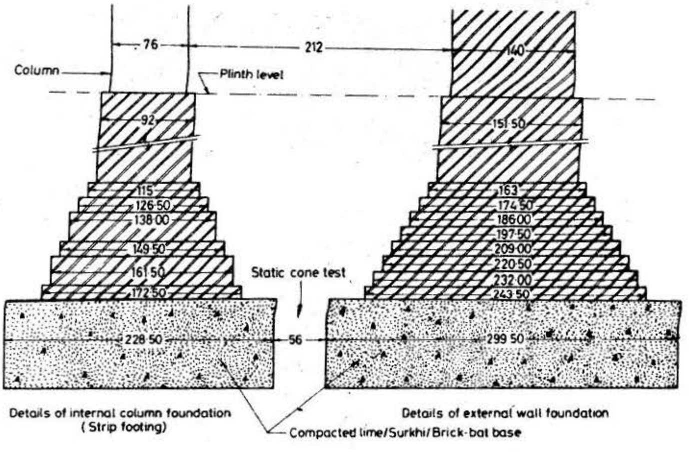

FIGURE 8 : Details of Strip Footings (Section A-A)

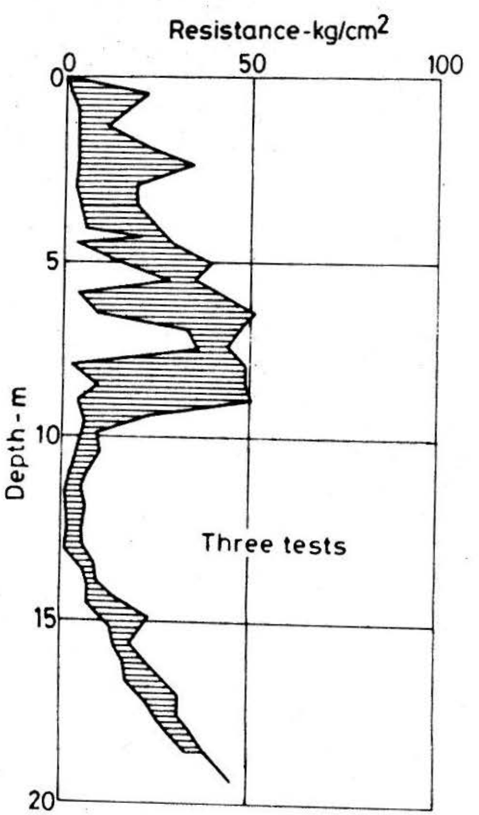

FIGURE 9 : Penetration Resistance with Depth

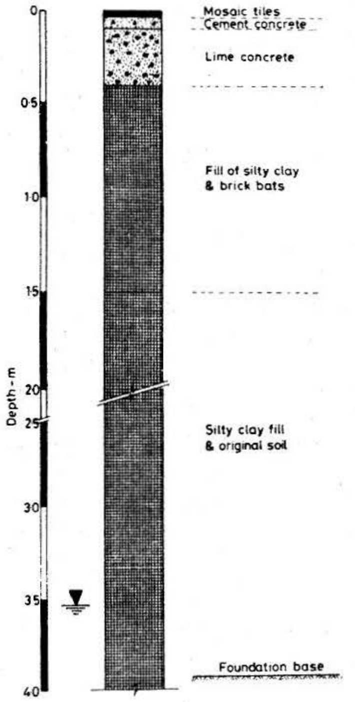

FIGURE 10 :
Strata Details in Gallery

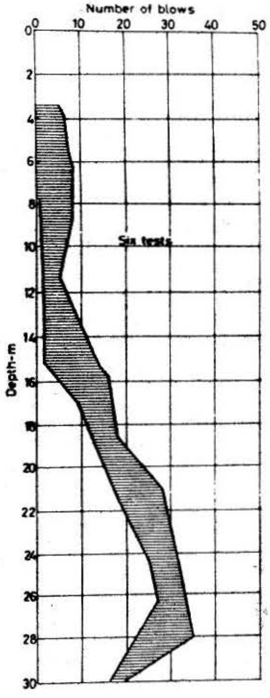

FIGURE 11 :
Penetration Resistance with Depth

Foundation Performance

The row of 76 cm × 76 cm columns at 4.64 m spacing is supported by 2.20 m width strip footing. The outer wall of 140 cm is on 3 m width strip footing. The estimated loads show that the pressures at base of the inner strip *is 3.68 t/m^2 and at the outer one 22.38 t/m^2. The difference* between the two pressure intensities is very striking. One major factor for this situation is the massive outer wall of 140 cm thickness. What was the basis of foundation design and their peculiar feature of close proximity at 56 cm clear distance defies a rational explantation. Obviously the bearing capacity, *if it was a consideration, was taken about* 22.5 t/m^2 *for the outer wall footing.*

Regarding the depth it seems justified as it is laid after bypassing the upper strata of lower strengths. It is said that there are other buildings of the same period having almost the same depth of foundations. It is also known that it has been a practice in the past that foundations were taken upto a depth where permanent water table or sand layer was reached. This practice is prescribed on Indian classical architectural texts also (Kulkarni, 1985).

The footing widths seem to have been decided by keeping the offsets such that the general slope from the plinth base is at about 1 : 2 (IS:1904-1973). Intensity of pressure does not seem to be guiding factor for their width and large variation in loading at two adjacent footings seems to have been ignored. On account of the erratic nature of strata, it is difficult to assign specific soil parameters for bearing pressure calculations. Generalised penetration resistance values seem to be better guide. Both the footings are of the same depth and quite close to each other (Fig. 8). They can be considered to act together, and averaging out of the minimum static cone penetration test values can be done within a depth 1.5 times their combined width. Silt fraction predominates in soil and clay is also present. The soils have a cohesion value of less than 0.5 kg/cm^2. For reducing static cone penetration resistance value to standard penetration N value a conversion by making them one third (Sanglerat, 1972) gives a N value of about 4. These values indicate a soil on low bearing capacity (IS:6403-1981). The estimated valued of safe bearing capacity for the present under water conditions are well below 10 t/m^2 (Peck et al., 1974). The loading intensity of 22.38 t/m^2 at the outer wall footing base is in excess even by bearing consideration. The settlement considerations also are to permit still less value of allowable bearing pressure (IS:8009-1976).

From settlement behaviour point of view the obvious problem is due to differential loading and erratic nature of soil deposits. The rise in water table is well known to reduce the bearing capacity. The configuration of the building and the foundation geometry is such that the foundations at the periphery of the building quadrangle are comparatively more heavily loaded. The first floor verandah is of lesser height then the gallery behind it. The differential settlements, even if the strata below were uniform all over, the outer walls should settle more and have a tendency to lean outward. This will enhance a cracking pattern wider at the top. The heavily loaded front side is more prone for such tendency. This is evidenced by vertical cracks in the middle of north and south blocks (Fig. 7). Differential settlements are visible in the inner courtyard. However, cracking of building is not due to this reason alone. Deterioration of materials and structural behaviour also add to the problem. Barring minor activity, settlement of foundations over such a large period should have stabilised. But inherent weakness of the choice of foundation configuration and their size is obvious. The general rise of water table and its fluctuations and general poor drainage of area have also added to foundation problems.

Concluding Remarks

The Indian Museum Building is an architectural heritage and in spite of best possible maintenance the problems are due to ageing of a massive brick structure in lime mortar and use of steel sections. On account of the conditions of building, restricted space and limited resources, the foundations are difficult to tackle for strengthening them. Also, the settlement of foundations should have stabilised during such a long period of time. Under the present circumstances, better drainage water management of both from rain water and services, and timely repairs and renovations to check seepage of water from roofs and floors are the effective measures. Provision of additional intermediate floors was not found feasible. A major programme of renovation and rebuilding is more desirable for solving the problem on permanent basis.

Acknowledgement

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