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# *Short Communication*

## Analysis of Collapse of a Building

*by*

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### Introduction

A multistorey building (one plus six) at Hyderabad suddenly collapsed on 31st October 1981 at 11.00 a.m. within minutes when it was almost ready for occupation by flat owners. There were twelve flats and a ground floor for shops and garages. Fortunately, there was no loss of life. The collapse acted as awakener to builders in twin cities of Hyderabad and Secunderabad, governmental agencies like Municipality and Urban Development Authority in realizing their respective roles and responsibilities. It has also proved to be educative in emphasizing the importance of proper site investigation, design, execution, quality control, choice of building materials and components.

Nayak (1982) described the failure in a very casual way on the basis of his first impression and probably in an apparent study. Iqbal Ali et al. (1982) after careful study concluded that factors which initiated instability could not be positively identified. Author's study of failure reveals that there is a definite proof for identification of primary cause for failure due to choking of storm water drain passing underneath the building resulting in liquifaction of sandy clay strata adjoining the drain and temporary loss of lateral support to piles leading to instability and total collapse of the building like a pack of cards.

Special feature of the project is that the promoter, architect, designer and builder are from one organisation.

### Building Complex

The collapsed building A (shown latched in Figure 1) is one of the seven buildings located in the area measuring about 8000 square meters. The area was relatively low lying with a storm water drain passing through it and had been under wet cultivation for sometime. The drain was passing under the collapsed building which could not be diverted because of property line being very close to the collapsed building. The drain has been diverted for the rest of the buildings as shown in Figure 1. The sides of the portion of the drain under the collapsed building were of coarse rubble

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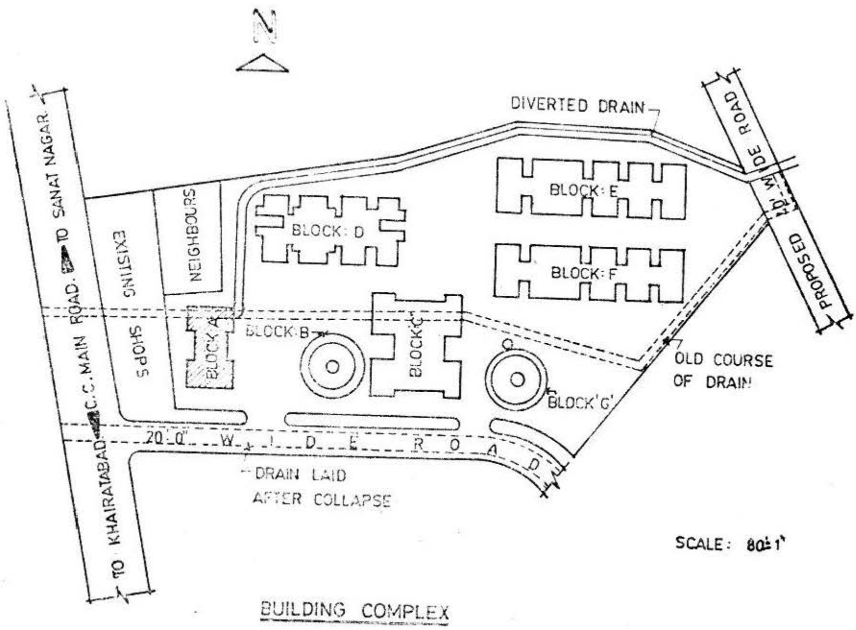
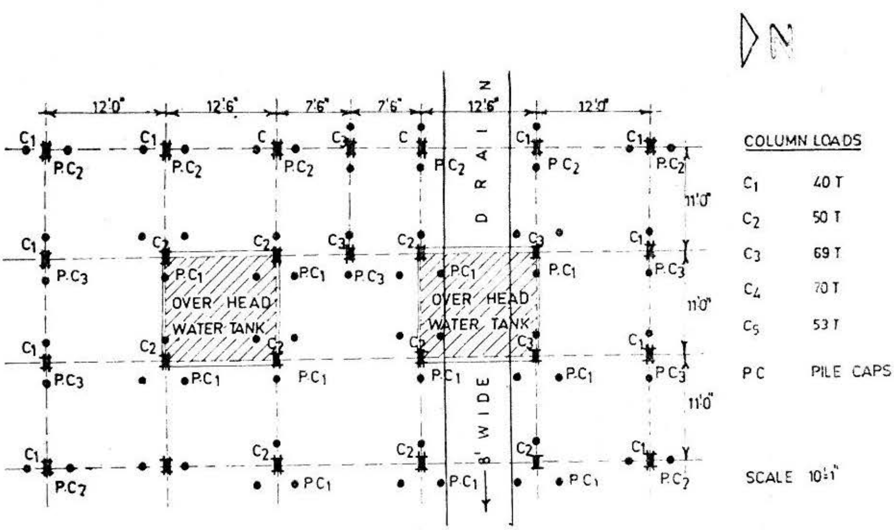



**FIGURE 1** Site Plan

masonry pointed with cement mortar and covered with R.C.C. slab before the construction of building (after the collapse, municipality built a large capacity closed drain for storm water passing below the southern side road).

Buildings A, B, C, D and G rested on double under reamed pile foundations. Buildings E and F are on individual column footings laid on hard stratum by open excavation.

Pile foundations consisted of 15″ (38.1 cm) diameter stem double under-reamed at 6′ (1.8 m) and 10′ (3.0 m) depths having bulk diameter of 3′-1″ (94 cm) driven to a depth of 4 m. Two piles have been used for under 50 t load columns and three piles for columns carrying higher loads maximum being 70 tonnes. Figure 2 shows pile locations and column loads. Figure 3 shows pile and pile cap details. Pile spacing is 5′-6″ c/c (1.6775 m c/c). Pile reinforcement consisted of 6 Nos. 12 mm $\phi$ longitudinal bars and 6 mm $\phi$ stirrups 15 cm c/c as against 5 Nos of 12 mm $\phi$ for longitudinal reinforce ment and 6 mm $\phi$ stirrups 30 cm c/c suggestnd by IS : 2911 (part III)-1980, giving load carrying capacity of 30 tonnes for 37.5 cm. dia. pile. Design is based on National Building Code and visual assessment of geotechnical properties. RCC components have been designed as per IS : 456-1964. M 15 was used for piles, beams, floors and M20 for columns. Pile caps were connected by beams to transfer the load of the ground floor walls to pile foundations. Steel shuttering was used for RCC work. Mixers and vibrators were used for mixing and compacting the concrete to achieve




PILE CONFIGURATION AND COLUMN LOADS

**FIGURE 2 Piles, Pile Caps and Pile Loads**

quality. The building was completed in about two years (October 79 to Oct. 81). Pile load tests were not done which is an obligatory in all important pile foundations.

## Geotechnical Properties

Post-failure investigations on foundation soils were conducted to investigate the failure causes. Standard penetration tests, cone penetration tests were carried in the area and some of them on the eastern side of the collapsed building. The probing data was supplemented by few bore holes from which undisturbed and disturbed soil samples were collected and tested in the laboratory (Appendix A). Bore holes were drilled to a depth of 6 m where relatively hard disintegrated rock is met with and standard penetration tests recorded refusal to penetration. N values below 1.5 m depth varied from 25 to 40. Ground water level at the time of investigation was 1 m below ground surface.

The top soil adjoining the drain has following properties :

| | |
|---|---|
| Sand, 4.75—0.075 mm | 52% |
| Silt, 0.075—0.002 mm | 17% |
| Clay, <0.002 mm | 30% |
| Sp. Gr. Soil particles | 2.60 |

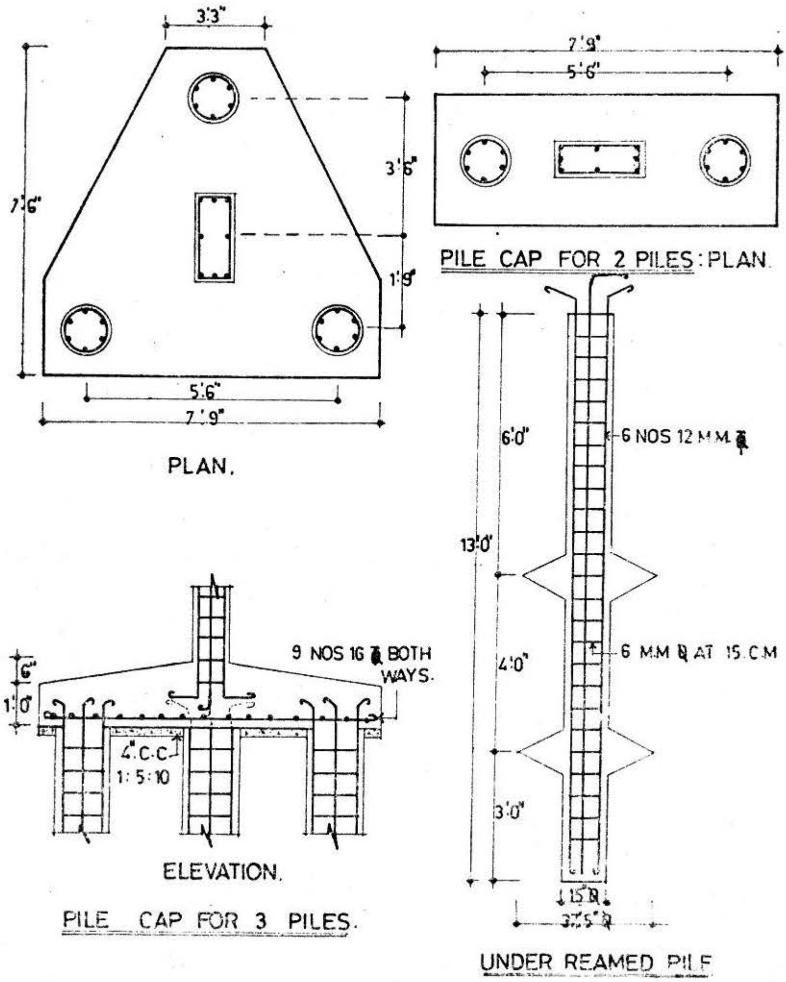



**FIGURE 3 Details of Pile and Pile Caps**

| | |
|---|---|
| Bulk density | 1.88 g/c.c. |
| Dry density | 1.43 g/c.c. |
| Natural moisture content | 31.5% |
| Liquid limit | 43% |
| Plastic limit | 25% |
| Shrinkage limit | 14.5% |
| Plasticity index | 18 |
| Unconfined cnmpressive strength | 90 KN/m$^2$ |
| Maximum dry density | 1.95 g/c.c. |
| OMC | 11.5% |
| Soil type | Sandy clay |

Soil has also been studied for liquifaction characteristics in the laboratory and it is reported that the top soil gets liquified under seepage forces and erosion takes place (Khalid, 1982).

**Tests on Concrete**

Concrete cores of 100 m dia were cut out from the intact portions of beams, columns and pile caps and were tested for compressive strength in accordance with IS : 516-1959 and IS : 456-1978. The equivalent cube strength of concrete beams has been found to be 250 kg/cm$^2$ whereas those of columns and pile caps varied from 60 to 150 kg/cm$^2$. Honey-combed concrete in pile caps was evident from cores (Iqbal Ali et al., 1982).

**Analysis of Collapse**

On 29th and 30th October, 1981, heavy rain was experienced in the area. The drain passing under the building ran full under pressure and probably choked. On 30th October 1981, noise of falling of plaster was heard in the building which was not cared for. On 31st October at 9.30 a.m. site office wall located by the side of drain on ground floor fell down with rumbling noise. Sensing the danger, workers in the building were vacated. At about 11.00 a.m. collapse of the building started with sinking of NW corner column by few centimeters and building collapsed like a pack of cards within 10-15 minutes giving out huge noise and dust. Fortunately, no loss of life occurred.

Figure 4, is the view of the building before collapse. Figure 5 and 6 are the views of collapsed building from eastern side and north-east corner respectively. Figure 7 shows building after pulled down by demolishion squad and the neighbouring structure on which it leaned. Figure 8 depicts nature of collapse of first and second floors falling one over the other under impact and punching action of ground floor columns through pile caps into the ground. North-east corner column punched completely into ground whereas south-east corner column is about 2 m above the ground. Figure 9 depicts punching of column through pile cap and also coarse rubble stone face of the drain adjoining pile cap. Figure 10 shows deformation of drain, tilting of piles along drain on either side towards drain. Figure 11 shows north-west corner column which sank first in the process of collapse vertically though during collapse building leaned towards north-west. Figure 12 shows close view of inclination of column and piles by the side of drain which are not in the same direction. Piles have tilted towards drain whereas column towards north-west. Figure 13 shows cracking of plinth beam adjoining drain where office wall collapsed first as a warning to workers in the building. Figure 14 gives tilt directions of piles, deformation of top soil and drain and also penetration of eastern face of columns. The building as a whole tilted towards north-west during

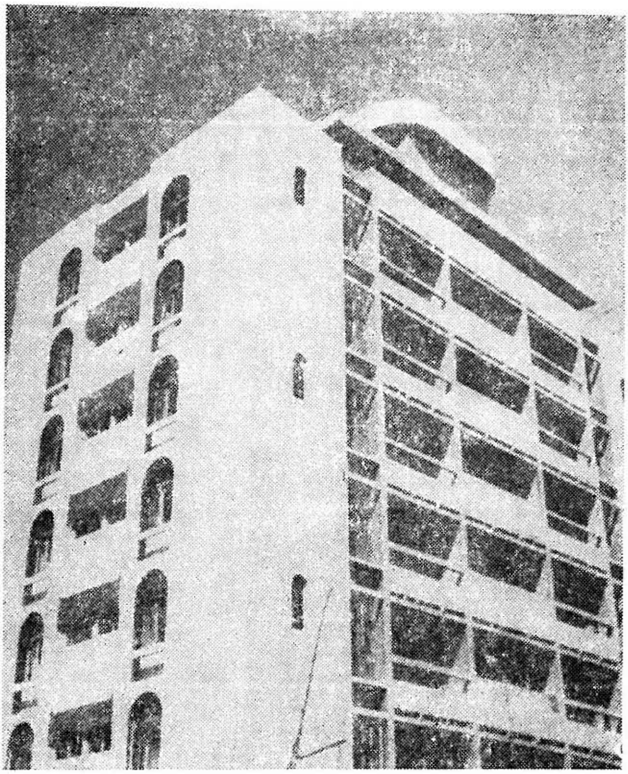


FIGURE 4 Building before Collapse

FIGURE 5 Building after Collapse (Eastern side)

FIGURE 6 Building after Collapse (North-West corner and North face)

FIGURE 7 Building after Demolishing the Struture and the Neighbouring Structure on which Collapsed Building Leaned.

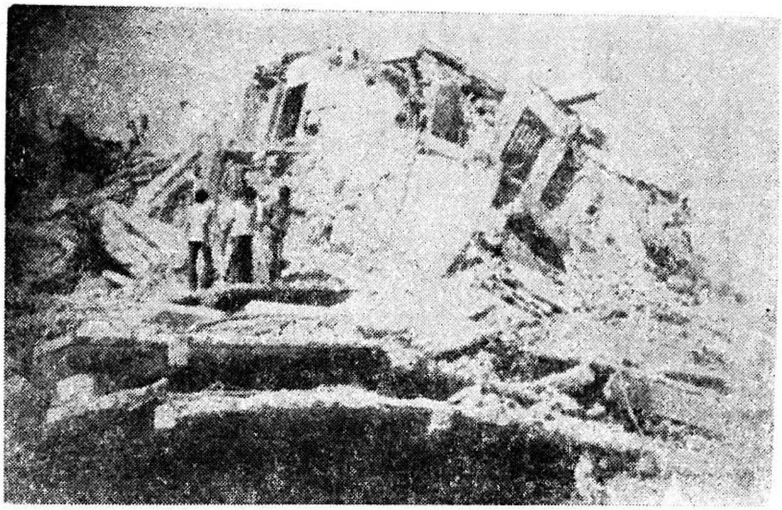


FIGURE 8 South-East Side of the Collapsed Building

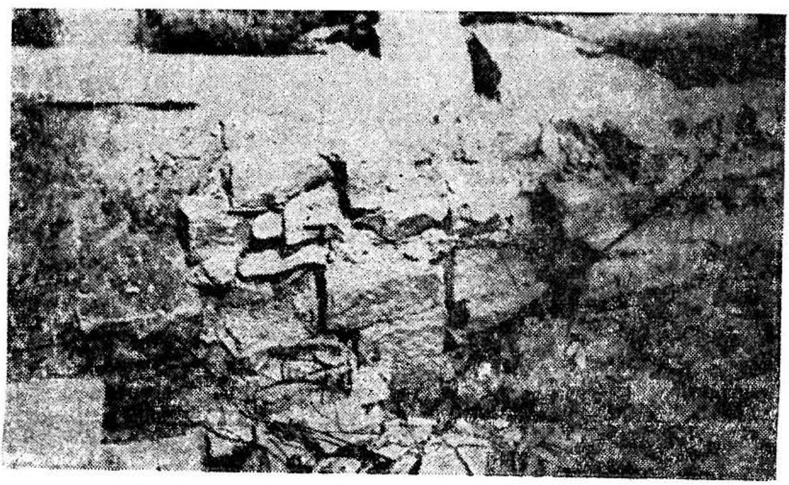


FIGURE 9 Punching Action of Column Through Pile Cap.

FIGURE 10 Deformed Drain, Piles and Columns below the Collapsed Building

FIGURE 11 View of the North-West Column which Punched First through Pile Cap and Piles and Adjoining Drain Beneath the Building.

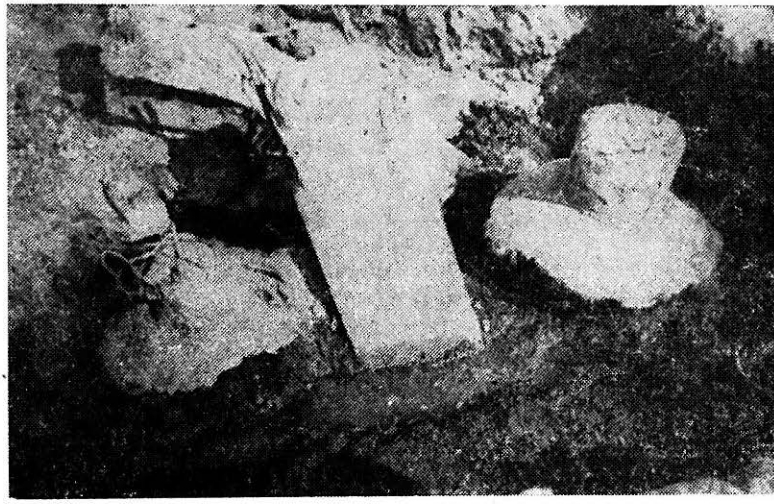


FIGURE 12 Configuration of Three Piles and Column by the Side of Drain after Collaspse Indicating Pile Inclination Towards Drain and Column Inclination Away from the Drain.

FIGURE 13 Cracking of Pile Cap Connecting Beam Supporting Office Wall which Crumbled First.

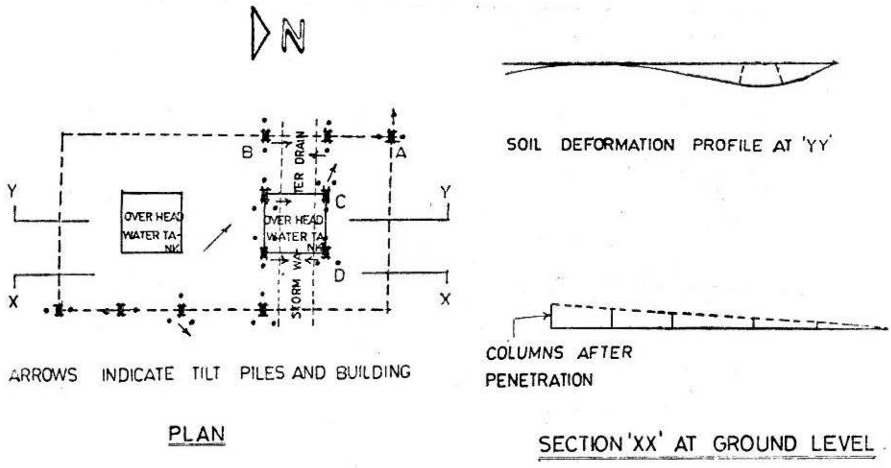



**FIGURE 14 Tilt Direction of Piles and Building and Soil Deformation Profile.**

collapse and rested on neighbouring building which has not damaged much. Portion of drain below the overhead water tank deformed in the form of bowl as illustrated in Fig. 4. Close examination of cleared site which is depicted in the form of photographs establishes the fact that the primary cause for collapse is existence of drain underneath the building and liquification of sandy clay over hard stratum due to heavy rain preceeding-the colla pse. This conclusion is further strengthened due to the fact that other buildings in the complex built by the same organisation under identical conditions except the absence of drain did not show any distress. At present, they are all occupied. However, subsequent to collapse of foundation of of building A, buildings B, C, D and G were strengthened by enlarging the ground floor columns with additional reinforcement upto ceiling and increasing the thickness of pile caps and providing inter-connecting beams to pile caps and columns.

## Conclusions

Primary cause of collapse of the building is liquifaction of top sandy clay adjoining storm water drain underneath the building which could not effectively discharge the rain water and resulted in tilt of piles towards the drain. This tilt is accentuated by the overhead water tank in the region of drain. Since the bottom soil was hard enough, vertical settlement of piles was not possible. Loss of lateral support due to liquifaction resulted in tilt of the piles initiating instability and insufficient thickness of pile caps (around 45 cm) resulted in punching shear (secondary cause) leading to total collapse within minutes like a pack of cards.

## Acknowledgements

Author is thankful to Sri B.N. Reddy who encouraged the study inspite of his great loss in the complex. Author is also thankful to authorities of Osmania University and his colleagues for their encouragement in the investigations.

**References**

IQBAL ALI, SAXENA, K.R., AND RAMKRISHNA, G. (1982) : "Collapse of a Multistoreyed Building" *Proceedings of National Seminar on Lessons from failure of structure,* Bombay, II/33-36.

IS : 2911 (Part III)—(1980) : "Code of Practie for Design and Construction of Pile Foundations-Under-Reamed Piles".

KHALID, S.A. (1982) - "*Liquifaction of Sandy Clay*" M.E. dissertation, Osmania University, Hyderabad.

NAYAK, N.V. (1982) : "Some Cases of Failure in Geotechnical Engineering, Causes and Remedies' *Proceedings of National Seminar on Lessons from Failure of Structures,* Bombay, I/45-50.

## Appendix : A

The location of bore holes driven after the collapse of the building and cross section of drain are given in the Fig. 15. Figure 16 gives log of bore holes and soil properties including S P T values. Bore holes indicate

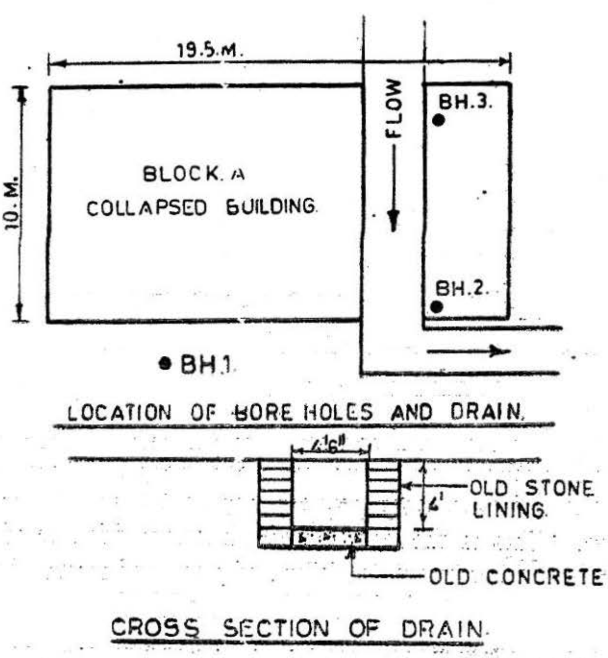



FIGURE 15 Location of Boreholes and Drain.

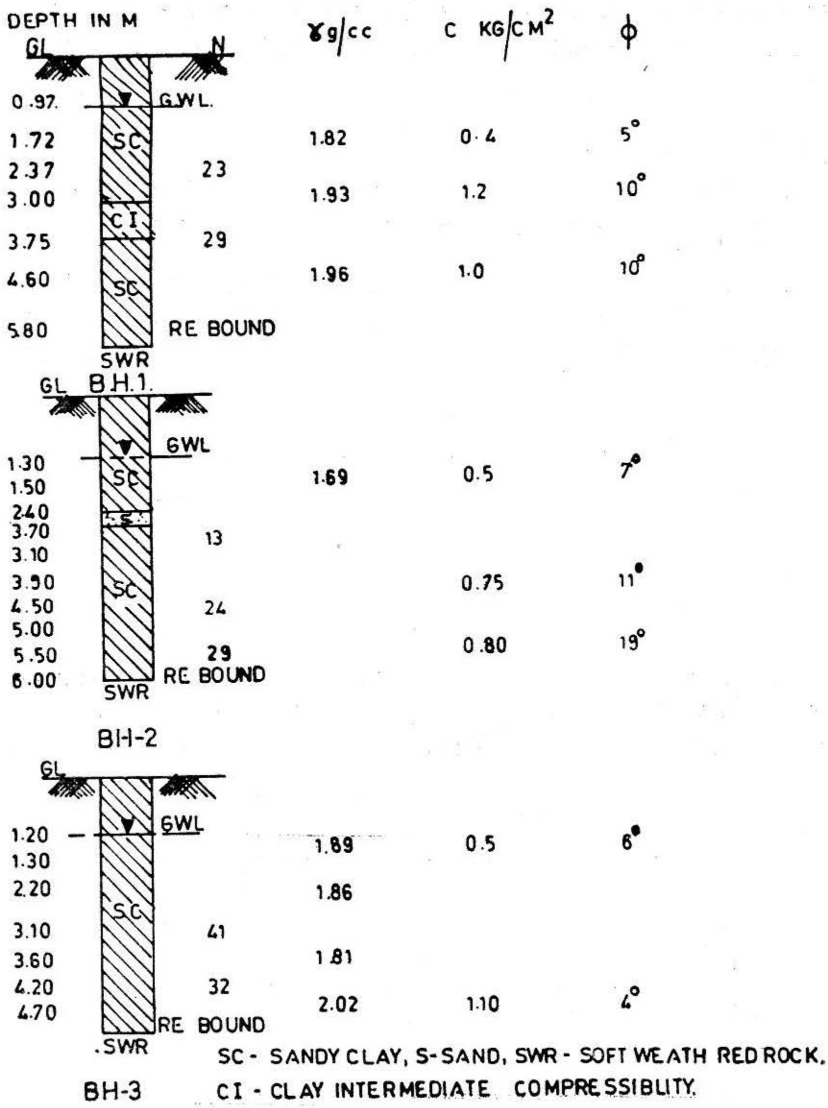



**FIGURE 16** Log of Boreholes.

that the hard strata is met with between 5 to 6 m below ground level. Soil above hard strata is sandy clay having low shear strength. Bore hole No. 2 indicates existance of sand layer between depths 2.7 and 3.4 mm below the ground level. This is the region where initiation of failure of building took place one day earlier by way of falling of plaster of ground floor partition walls.

Figure 17 shows experimental set up to investigate the possibility of

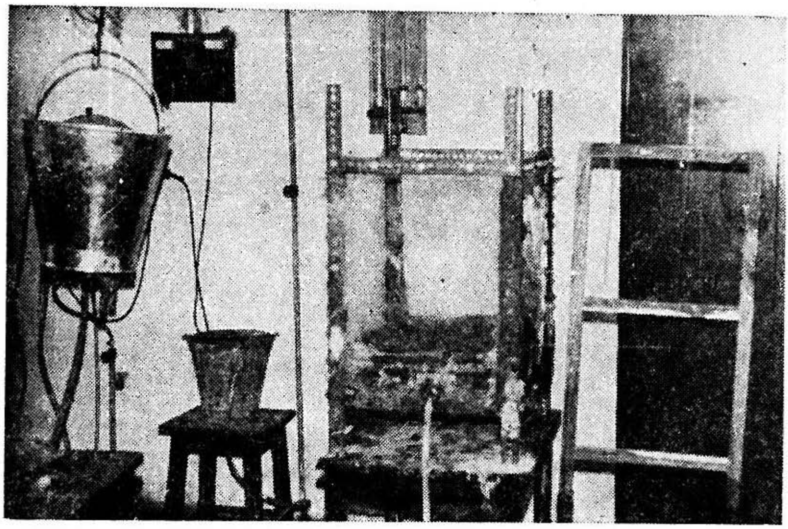


FIGURE 17 Test Arrangement for Study of Liquifaction.

occurrance of liquifaction due to saturation. Figure 18 indicates disturbance of soil under hydraulic pressure causing liquifaction.

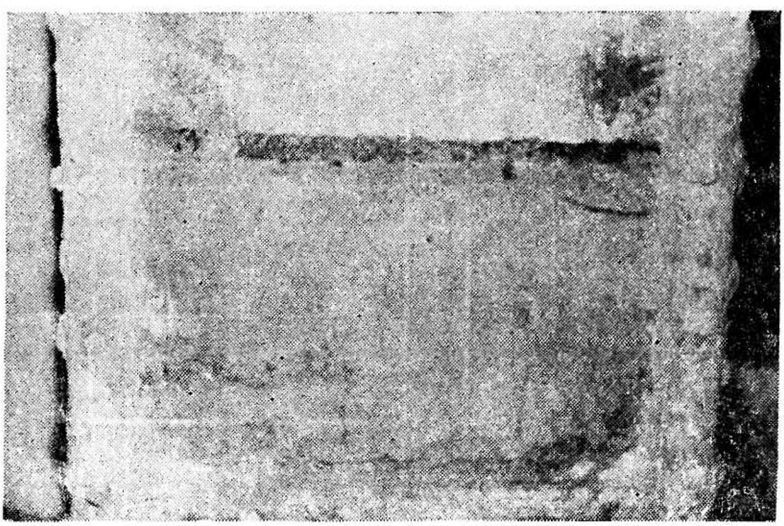


FIGURE 18 Soil Disturbance and Movement When Liquified in the Model.

Quantitative data could not be presented in this article but qualitatively from the photographs of foundation site and laboratory studies on the sample collected from the site of the building, it is concluded that initiation of failure of the building is due to liquifaction of upper sandy clay strata due to choking of drain whose size is obviously insufficient to discharge unprecedented rains two days before collapse.

## PUBLICATIONS AVAILABLE FOR SALE

1. Proceedings of GEOCON-India, Conference on Geotechnical Engineering, Dec. 1978, Vols. I, II, and III — Rs. 300.00

2. Proceedings of Indian Geotechnical Conference-83, Dec. 1983 Madras. Vols. I & II — Rs. 600.00

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