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A GEOTECHNICAL CASE STUDY OF FOUNDATION PERFORMANCE OF A BUILDING IN HOT WATER SPRING AREA

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ABSTRACT

A cold storage building on the bank of the river Parbati was constructed as both hot and cold water was available here in the natural source required for operating an absorption refrigeration machine. The building started showing cracks after two years of its construction. The pattern of cracks were suggestive of differential movement of foundation. Geotechnical investigation showed non-uniform strata at the site and seepage from the hot water bore hole which was not sealed around its periphery and was located inside the building was observed. Moreover, loss of finer material from sub-strata due to seepage towards the river in close proximity of the river had also taken place. These factors led to non-uniform bearing for the foundations and their differential movement, leading to development of cracks in the building. The distress in the building, vis-a-vis the geotechnical aspects of the strata alongwith the geological setting of the site are discussed and remedial measures for the rehabilitation of the building are suggested. Adequate field explorations before construction have been advised to avoid such problems.

INTRODUCTION

A building consisting of cold storage and its plant was constructed during 1981-83 at Manikaran in Himachal Pradesh. It started showing development of cracks in 1985 onwards which increased in intensity with time. The problem was investigated by detailed examination of the foundation and the substrata. The village Manikaran is in an apple growing area well known for its hot water springs of almost boiling water in close proximity of the Parvati river. The river water rarely exceeds 10°C temperature. This large difference of temperature was found suitable for operating an absorption refrigeration machine for cold storage of fresh fruits. A preliminary study had already showed that it should be possible to operate a cold storage using geothermal energy of natural hot water of spring in the generator of absorption machine, and cold water of the river in the condensor and absorber. Thus a pilot cold storage plant of 7.5 TR for apple was conceived and designed (Arora et al, 1983) at the instance of the Department of Non-conventional Energy Sources and the building was constructed to house the cold store and its plant.

Manikaran (32°02'N, 77°21'E) is located at an attitude of 1737m on the right bank of the river Parvati, a tributary of river Beas (Fig. 1). It is 37km from Bhuntar, a town on the main road from Manali to Kullu.

THE BUILDING

The river course at the Manikaran is approximately east to west and the whole village is situated on a terrace at the all foothill (Fig. 2). The cold store building is in the vicinity of Sri Ram Temple. The building is 14.22mx14 22m in plan (Fig. 3) having the office room and the Plant Room in the front portion with a covered passage in between the two leading to the Cold Storage area. The walls are of one-and-a-half brick thick, with 35cm thick plaster inside and exposed brick work in the exterior. The maximum height of the cold storage side walls is 9.33m while the front portion is about half of this height. The walls have 38cmx 23cm RCC columns in the brick walls to support the loads of the stored materials and the roof trusses with A. C. Sheets. There is three tier storage space having a clear headroom of 2.25m. The intermediate floors are of RSJs and wooden jafri. The finished floor level was in the front portion at 45 cm above the ground level. To accommodate the air space and RSJs etc. The floor level in the store is about 18cm lower than the ground level. Under the floor the filling was done by the local coarse sand and it had the usual specifications of 38mm top concrete finish over 76mm lean concrete. However, in store room floor, instead of lean concrete, the concrete as in top was used. The actual ground level was only a few cm below the floor level of the plant room.

THE HOT WATER SPRING WELL

For running the refrigeration machine both cold and hot water were required. The supply of cold water was by pumping from the river Parbati. For the hot water a bore hole was made by the Geological Survey of India at the plant site before the construction of the building. Now this bore hole is located in the Plant Room. For boring, casing was used and its diameter reduced with depth in steps of 186mm at top to 146mm, 85mm and 73mm. The total depth of the bore hole is about 60m. The top 25m length of hole lies in overburden, and the rest in Manikaran quartzite. It is important to note that the casing pipes were not cemented or sealed around their periphery in contact with the rock and overburden. The bore diameter increases towards top which is more than 2.5 times the lowermost diameter.

THE DISTRESS

The construction of the building was completed in 1983. The cracks were first observed in May, 1985 in the front and on the side walls of the building, subsequently further development of cracks were noticed. The building was inspected in detail in February 1987. The front portion of the building comprising the office room and the plant room (Fig. 3) showed separation of the walls at their junction with the cold storage. The cracks were wider at the top. The crack width in the Plant Room was 4.1cm at a height of 3.75m. Two prominant cracks had also developed on the side walls (Fig. 6 and 7) of the Office Room and the Plant Room. Besides, there were some diagonal cracks at window corners, a horizontal crack at the top of the lintel of the entrance passage door and several other cracks of minor and mixed nature.

The floor of the building also had suffered damage. Specially, the Plant Room floor showed irregular settlement though it was more in the centre. No special foundation treatment were reported to have been done for the various plant components which were not of large size and were fixed in the floor through bolts. The floor level of the store room in the rear is lower than the ground level and it had accumulated water in the space meant for air gap below deck for storing fruit. No waterproofing of this floor was done probably due to the fact that the permanent water table is well below the ground level, and the possibility of occasional water table rise above the floor level was not envisaged.

At the time of inspection the valve of the hot water well was closed as the plant was not under operation. However, there was continuous leakage from the valve and water collected in a small cavity around the top. As there was no outlet for this water, it was seeping into the floor and ground below. The local people who had seen the building under construction, reported that prior to the construction, the hot water was gushing out of the pipe. For starting the construction the pipe was plugged. But the site remained in very wet condition. It was also reported that after the construction there was sinking of the ground on the outside of the building, by the side of the front outer wall of the Plant room and water collected in the depression. Later on, this sink hole was filled up by dumping local sand.

The distress by cracks was not limited to the Cold Storage Building alone. Another building, a Tourist Complex, at about 10m away across the passage in the front had also suffered from extensive cracking and subsidence of ground, and differential settlement of foundation were noticeable in the complex which is almost on the river bank. Bank erosion is also evident in the area. The fine soil particles got washed away by the water current and also by the seepage through the ground towards the river. The river bank is 40 to 50m lower than the terrace. Occasionally cracks in the ground are noticed when flood recedes. In 1986 one such crack almost parallel to the bank was about 60m long. It got filled up later. Close proximity of river having its curvilinear course, seepage through the terrace and presence of hot water springs under artisan pressure add to the instability of the site.

HOT SPRINGS AND THEIR GOELOGICAL SETTING

Manikaran, a small village situated about 45kms from Kulu is known for the occurrences of hot springs at many locations mainly in the Manikaran-Kasol area and at Khirganga. A large number of hot springs having their temperatures from 41° to 97°C are present on the right bank of the river. The hottest cluster of hot springs of India are known to occur in this region near Harihar temple. These exhibit geysor activity and have large discharges. The hot springs generally emerge either from overburden or through river terrace deposits overlying jointed quartzites. The thickness of the overburden has been estimated to be varying from 25m to 30m. At some locations hot springs issuing from the joint planes in the quartzites are also seen. In general, all the springs emit CO_2 and H_2S. The maximum height to which the spring water rises from the spots is about 50 cm. However, at one location near the temple the spring water shoots to about 1 metre height at an angle of 45°.

The main rock types exposed in the Manikaran-Kasol hot spring area are mainly massive quartzites with lenticular bands of chlorite - phyllites belonging to pre-cambrian age (Fig. 8). The other rock types found in Parvati valley region comprise granite, gneisses, quartz-mica schist and basic intrusive rocks. The quartzites are mainly exposed between Manikaran and Jari, having regional dip ranging from 30° to 50° in north-east direction. Towards the south of this region, granite gneisses are exposed which have been considered as magmatic intrusion into the quartzite and are equivalent to Panjal traps (Post Carboniferous age).

The quartzites are generally highly jointed and fractured having three sets of joint planes. The presence of three sets of joints has great significance so far as the movement of hot waters at shallow depths in Manikaran and Kasol region is concerned. The quartzite is overlain by gneisses, schists and carbonaceous phyllites of the Kulu Formation. The contact between Manikaran quartzite and Kulu Formation appears to be a major thrust contact. The Kulu Formation is thrusted over the Manikaran Formation and these are older than quartzites. Hot spring at Khirganga emerge through these overthrusted sheets in the upper reaches of Parvati valley which are comparatively less jointed as compared to Manikaran quartzites.

There are two distinct hydrogeological units identified in this valley. The first unit comprises river terrace deposits, valley fill material and alluvial cones. It contains water under unconfined conditions. This unit is underlain by thick, highly jointed and fractured quartzites and phyllite which form the second unit. This unit forms the main potential reservoir for hot water. In a ddition, recharge of both the aquifers take place from melting of snow at upper reaches of the valley and from surface precipitation.

FOUNDATION PERFORMANCE AND STRATA

The building is located on a terrace close to the river. The thickness of overburden here is about 25-35 m. The foundation of the building has been kept at 1.4 m depth in sand and gravels. No soil testing had been done before construction to know the properties of the foundation material. Of course, there was ample general information that the strata was of cohesionless material varying in size from sand to boulders deposited by the river and accumulated at the foot of the hill. During excavations erratic deposits of gravel/sand were of common occurrance at the site. The strata under the storage building was although almost of the same composition, but was more compact in nature. As against this the strata under the front portion of the building was reported to be less compact and was very wet. It is also to be noted that the ground here is generally sloping towards the front side of the building. The rear portion, which is toward the hill side, is more compact and has better bearing capacity.

The width of the strip footings is 1.05 m and the column footings are 1.80 m x 0.97 m in dimension. Their depth is about 1.35 m in both the cases (Fig. 4 & 5). Reinforced concrete bands have been provided in the building and these are connected to the columns. There are two bands in the storage room walls which are higher. These bands seems to have been provided as an anti earthquake measure as the site is in earthquake Zone V. The quailty of the masonry and concrete work was according to the specifications. Reasons for cracking could not be attributed to the performance of the superstructure as there was no deterioration of the materials and there was no excessive loading. The plant did not run and there was no storage of materials. The substructure performance, including behaviour of strata could be the reason.

The foundation of the walls and columns are of the same description for the whole building. It seems that for foundation design, loads might have been worked out for storage portion and the same foundation had been adopted all over the building. The bearing area of RCC footing is 1.80 m x 0.97 m and if 5t/sq. m. were the bearing pressure, the footing can safely carry a load of 17.50t. Similarly a one meter length of strip footing of 1.05 m width will carry a safe load of 5.25t. These back calculations reasonably match with the expected likely loading in the storage portion In fact, these are on safer side and excessively so for the front portion,' where there is no storage, and wall heights are almost half. The assumption of safe bearing pressure of 5t/sq. m is the lowest likely value for cohesionless soil strata. Thus, it can be concluded that foundations are adequate, and under normal case there should not have been any problems on account of their performance.

The nature of cracks in the office room and in the Plant Room is indicative of foundation movements. The wider cracks at the top and cracks on the side walls show that the front portion consisting of the office room and the Plant Room have suffered from differential settlement of foundations. The general slope of the ground is towards the river and the flow of water, both the surface water and the underground seepage water, is also in the same direction. Also the development of the sink hole adjacent to the front wall indicates that there had been potential danger of differential settlement of the front outer wall foundations. Assuming that front portion has gone down by tilting towards outside in the same proportion as indicated by the crack width of 4.1 cm at 3.75 m height, the calculated magnitude of settlement of the front wall foundation is 7.0 cm. However, this settlement and consequent tilt are not expected to be uniform throughout the length of the wall.

The development of the sink hole is an indication of the likely loss of materials in the lower strata. The hot water bore hole is not sealed around the casing in the rock and overburden, and the water is under pressure. Of course, the increasing pipe diameters towards the ground will reduce the intensity of pressure but upward flow of water continues from all possible space around the casing pipe, specially when the valve is closed. This water will seep into strata comprising permeable sand and gravel. This can lead to washing away of the finer sand fractions of the strata which, in turn, can lead to the subsidence of ground. The distress in the Plant Room floor is on account of continued seepage of water from the hot water well. The drawings indicate a difference of 45 cms. Obviously, material brought by rain water has been deposited in the front side passage. Seasonal rains and water on the surface have found access in the Storage room and accumulated over the floor which is lower than the ground level. Even otherwise, cycle of wetting and drying by water or rising and receding water table are not conducive to good performance of floors. Such situations can lead to non uniform sinking and development of cracks, which are seen in this case.

The location of the hot water spring well under artisan pressure inside a small size room crowded with several other plant fittings was not a right decision. The seepage of water under pressure is bound to occur into the permeable strata and natural crevices.

PROPOSED REMEDIAL MEASURES

The building cracks can be repaired by filling, stitching and rebuilding and relaying of the floors. The problem has been due to seepage of the water and consequent likely loss of material from the ground which has resulted in the differential settlement of foundations. The underpinning of the foundations is not feasible due to techno-economic reasons of elaborate nature of such operations. limited working space and cost The sealing of the casing into the overburden on its outer periphery is also not practical at this stage. Under this situation effectively directing the seepage water seems more practical (Dinesh Mohan and Devendra Sharma, 1964). The seepage water affecting the foundations can be cut-off by providing deep drains around the building, so that water dissipating around the well or coming from area around the building is cut-off from affecting the building foundations and floors. The floors of the front portion will need relaying over a bed of boulders and gravels, topped by sand, so that water may freely drain through it. A gravel filled filter, around the hot water well casing, upto a depth of 2m or more and of about 1 m diameter should be provided for quicker dissipation and localising the seepage from around the casing.

The entire river bank is prone to erosion and long term measure ensuring stability of the entire Manikaran terrace call for directing the river current and protection of the curved river bank. A proper channelisation of the river for about 250 m along the curved portion is needed. This could be done, say, by boulder filled wire mesh crates. Provision of spurs on both the banks alongwith the deepening of the mid stream can also help. Any further borings for tapping hot water should be in a planned manner and implications of seepage from around the casing should be appreciated. The uncontrolled seepage induces loss of terrace material as the river is in close proximity and seepage water flows into the river.

CONCLUDING REMARKS

The case history brings out that the lack of appreciation of geotechnical factors result in serious difficulties. The problems could have been anticipated had proper field investigations been done in advance. Unsealed hot water well and close proximity of the river has further aggravated the problem. Under the present constraints to stablise the building, remedial measures like directing the seepage water is the most practical solution.

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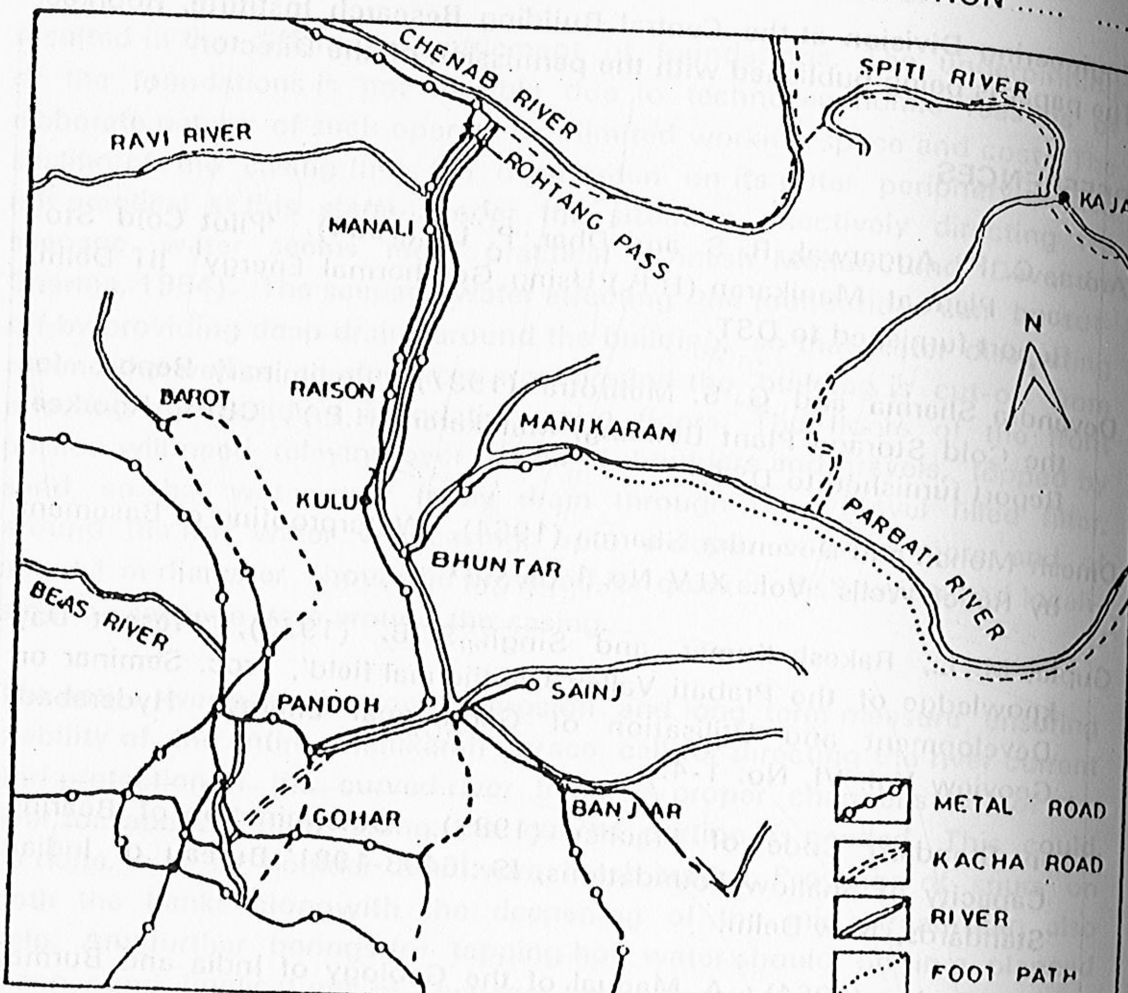

Fig. 1. LOCATION MAP OF MANIKARAN

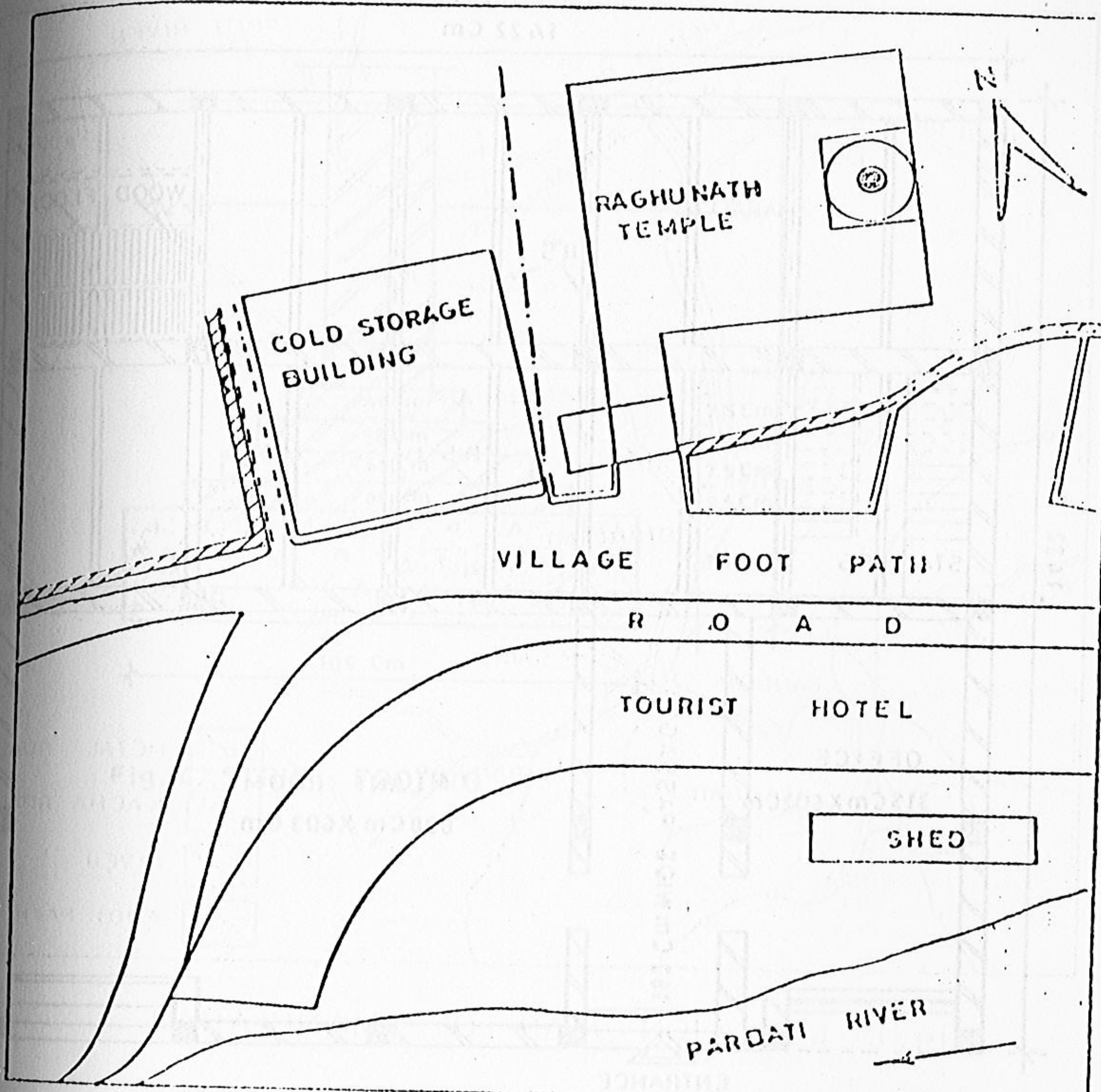

Fig. 2. KEY PLAN

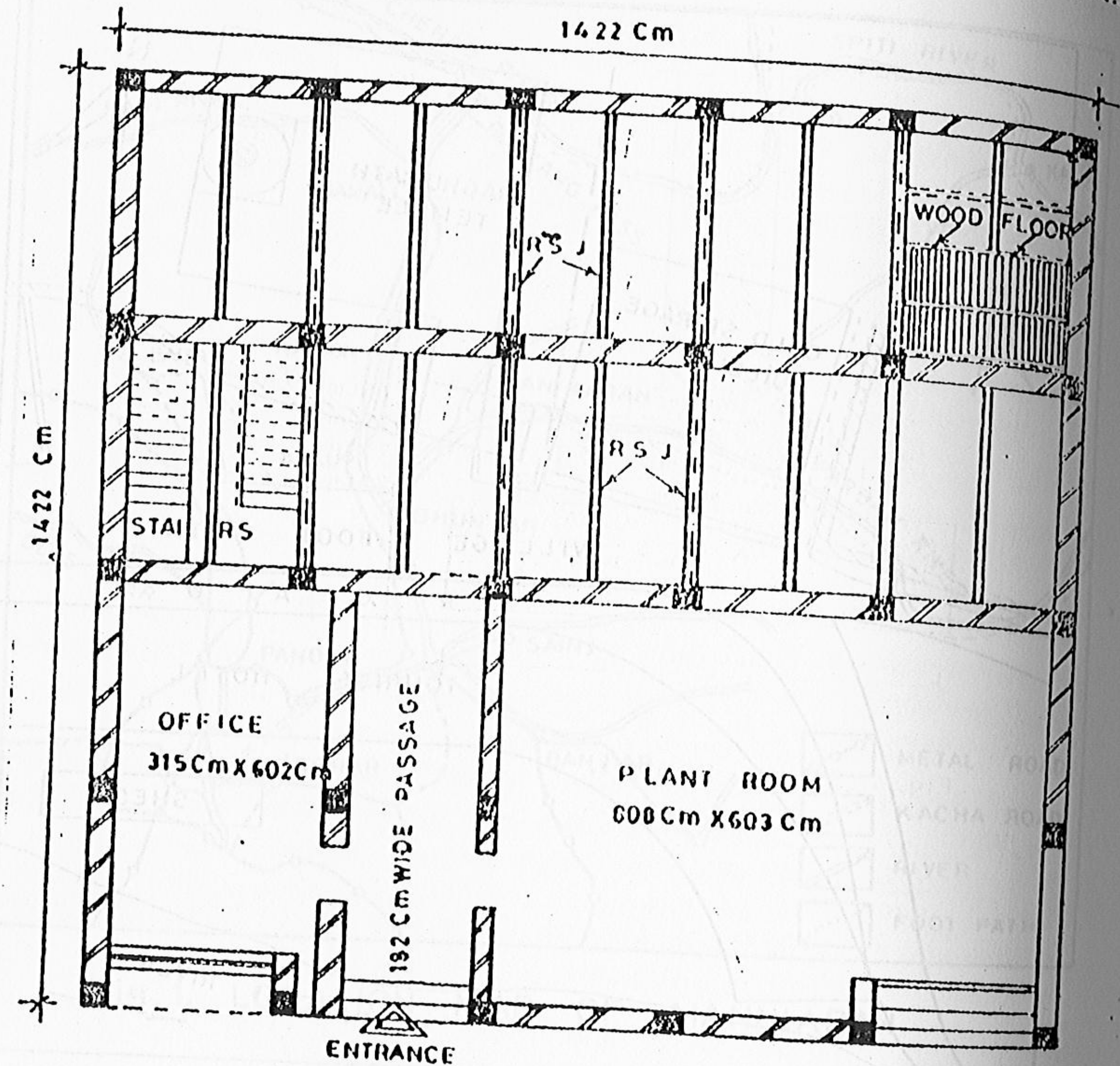

Fig. 3. GROUND FLOOR PLAN

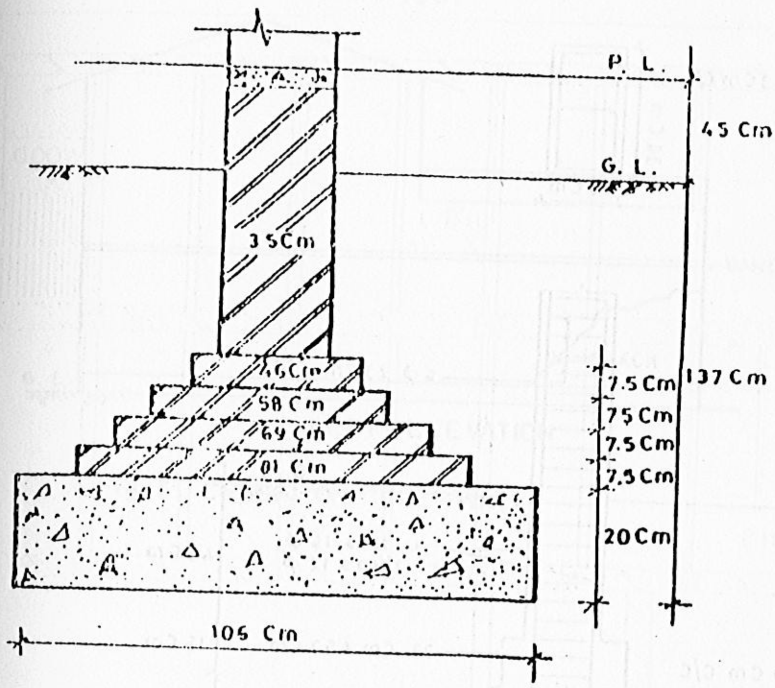

Fig. 4. STRIP FOOTING

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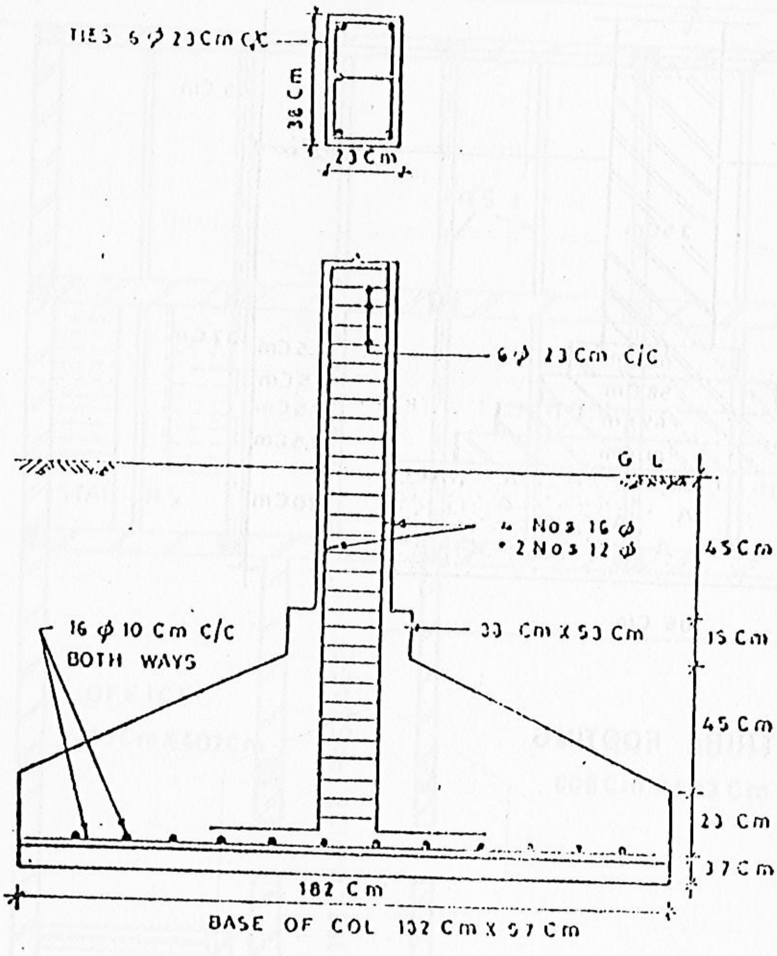

Fig. 5. DETAILS OF COLUMN

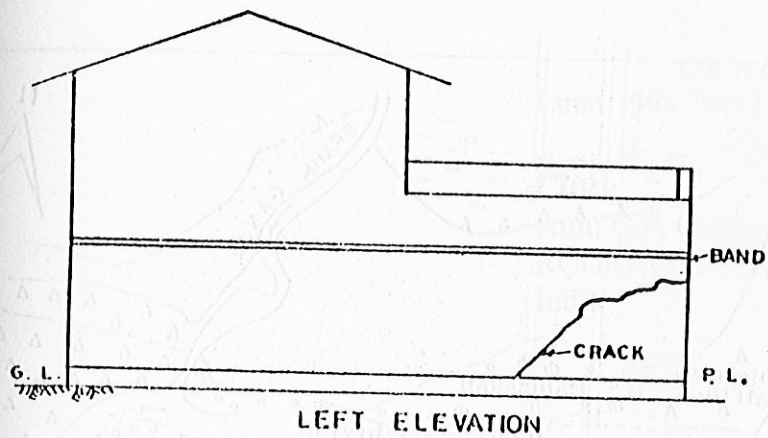

Fig. 6. CRACK ON SIDE WALL

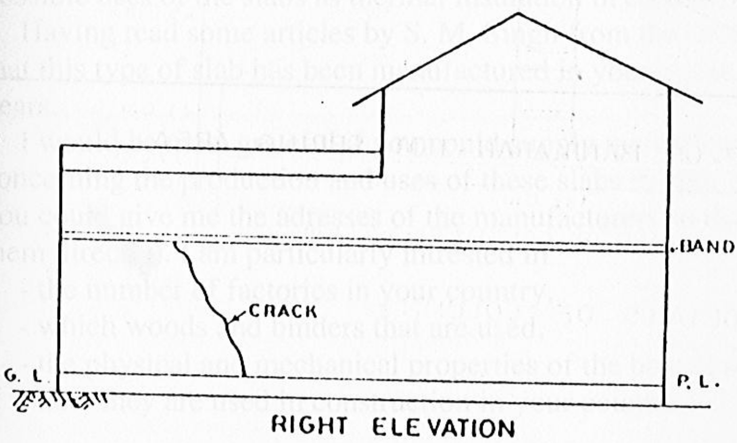

Fig. 7. CRACK ON SIDE WALL

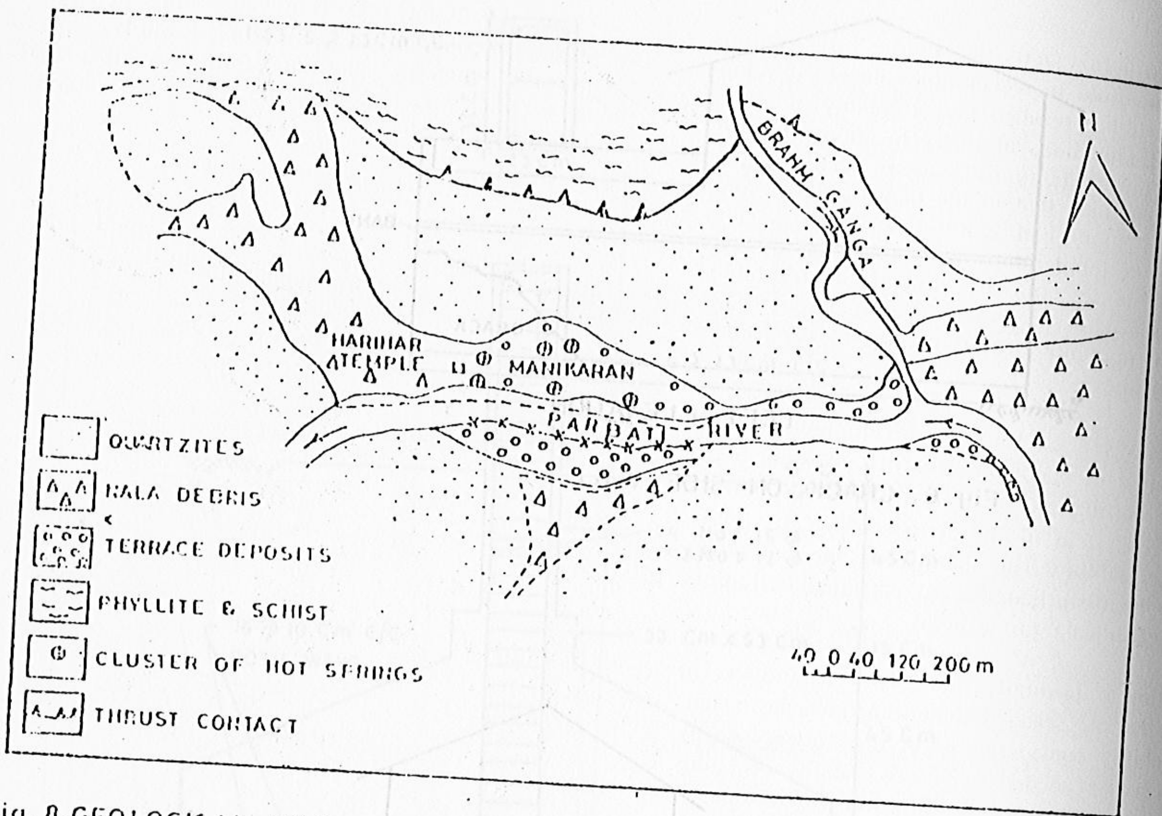

Fig. 8. GEOLOGICAL MAP OF MANIKARAN HOT SPRING AREA