Recent Trends In Foundation Strengthening

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Modern foundation engineering can come to the rescue of structures that have experienced significant foundation distress or failure. Detailed investigation of cause and mode of failure together with careful planning and sound engineering practice is the key to successful execution of the foundation strengthening process. Specific case histories of some projects in Delhi and Bihar are described explaining the nature of foundation distress and methodology adopted to stabilize the structures and ensuring adequate foundation performance.

Collapse Of Residential Building Foundation

A portion of a two storeyed residential building in New Delhi experienced sudden loss of foundation support after heavy rains. Earlier investigations in the project area had revealed the presence of rocky formation at shallow depths. The foundations constructed on the rock were designed for a net bearing pressure of 12 t/sq.m.

This apparently baffling situation was investigated in great detail to identify the cause of the foundation failure. Local information revealed that some abandoned mines for mica existed in the vicinity of the area. To locate the possible presence of underground cavities/mining tunnels etc., CBRI Roorkee performed georadar tests supplemented by drilling of deep bore holes as well as electrical resistivity tests undertaken by Cengrs.

Based on the results of the investigation, an underground tunnel was located as passing below the kitchen portion of the flat that had sunk and below the bedroom of an adjacent flat. Cengrs then exposed the cavity and removed all loose debris etc., so as to assess the extent of the cavity.

Taking advantage of the fact that the plinth beam had not experienced any significant distress, Cengrs designed and installed a new foundation system for the flat. The new foundation system was site specific, taking into account actual local conditions. The highlights of this foundation strengthening process were -

(a) Filling all inaccessible portions of the cavity and channels by pumping sand and pressure grouting with cement grout.

(b) Installing 300 mm diameter auger piles through the weathered murrum mass to bear on firm rock and grouting the pile tip.

(c) Constructing a RCC beam on top of the piles and raising brick work upto the bottom of the plinth beam and grouting the interface to ensure load transfer.

(d) Constructing concrete plugs in the channels away from the building area to provide a cut-off. The top of the cavity was filled with lean concrete over the sand to restrict seepage of water.

A schematic sketch is presented

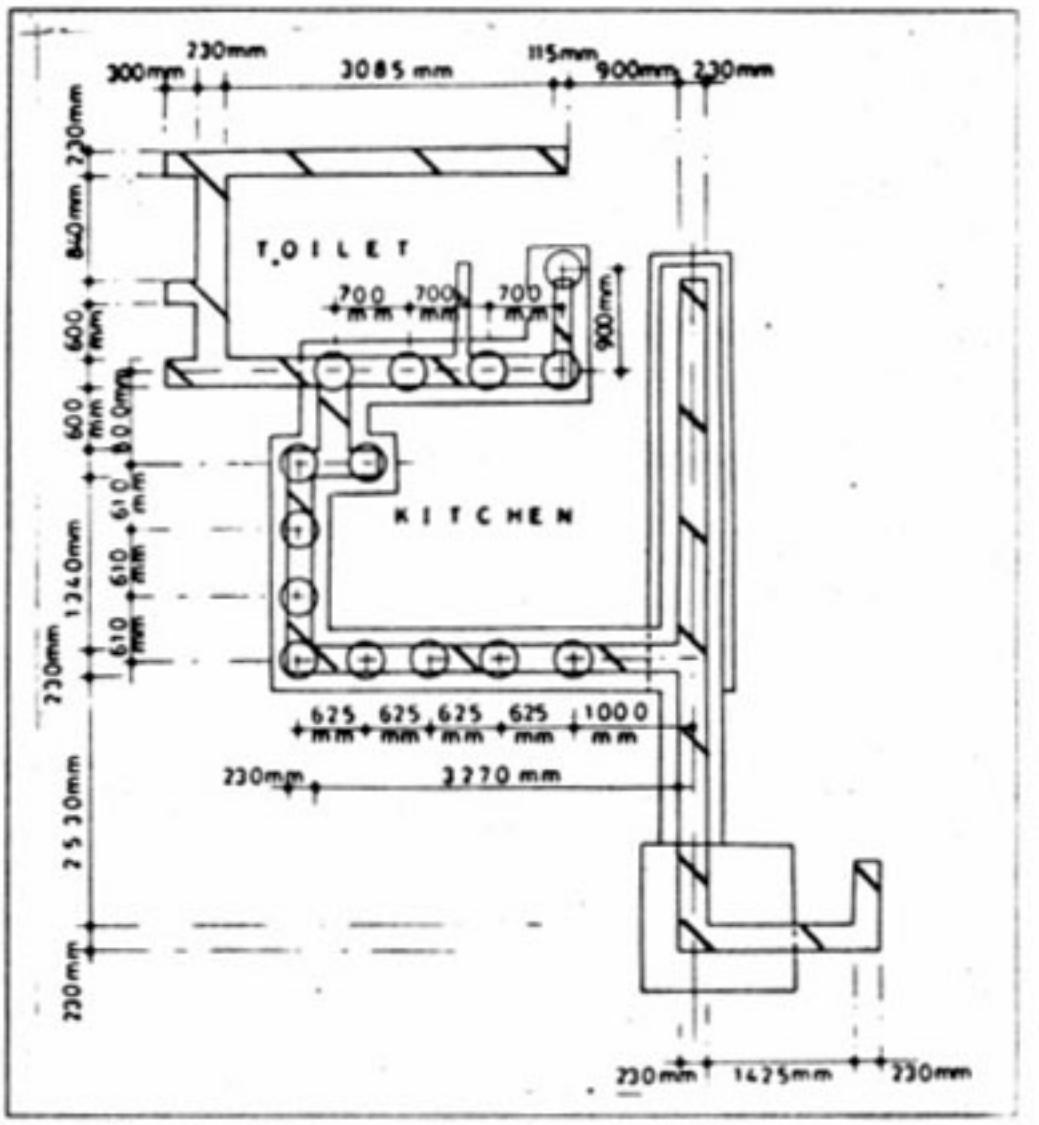

Fig. 1. New Foundation System For Collapsed Residential Building.

in Fig. No. 1 indicating the pile configuration.

This foundation strengthening was performed under limited working conditions, exposing small sections at a time so as to preclude any further structural damage and proceeding from one section to the other after providing adequate support.

Tilting Of Overhead Tank

An overhead tank at New Delhi had experienced some tilt even before the with was filled up with water. Soil investigation revealed that the underlying silty soil was in loose state till about 4 to 5m depth below which a dense gravel layer was present. The tank was supported over raft foundation of 8.5m diameter and the tilt was due to excessive settlement under a part of the foundation. The cause was identified as being due to migration of fines when flow of ground water took place. In order to arrest further settlement/ tilting of the tank, Cengrs developed a scheme for providing a curtain wall to arrest any further migration of fines/soil particles. The scheme comprised of installing 300mm dia bored piles at close spacing all around the periphery of tank raft foundation. A conduit pipe was provided in the pile bores and the underlying gravel layer was grouted through the conduit pipe after the pile was concreted. In the second phase, grout holes of 75mm dia were drilled in the space between the piles and the raft foundation upto the gravel layer. The grout holes were plugged at foundation level upto gravel bed was pressure grouted with cement slurry under a pressure of 2 to 2.5 kg/sq.cm.

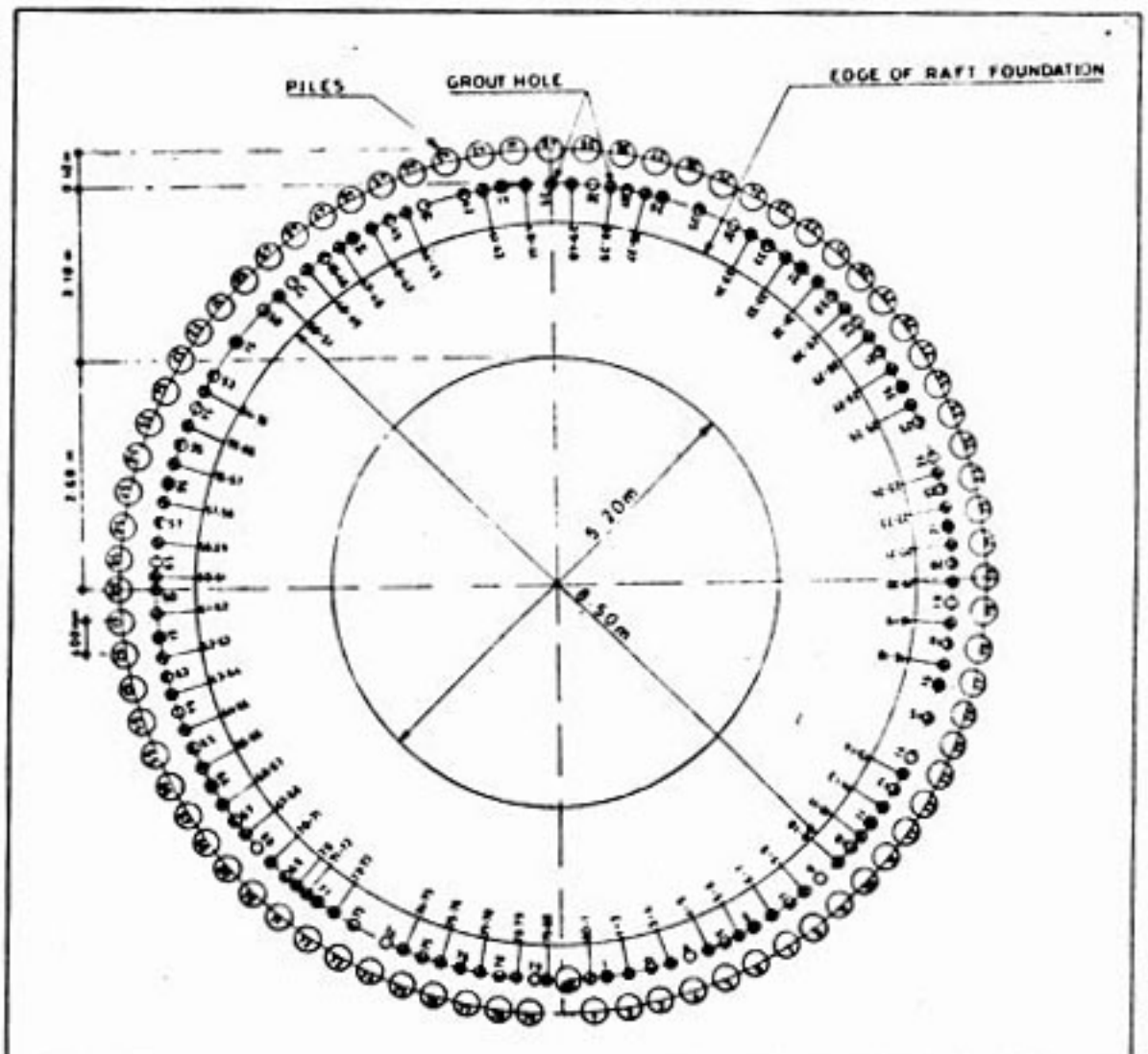

Fig. 2. Arrangement Of Piles & Grout Holes For Strengthening Foundation Of Overhead Tank

The sequence for providing piles and grout holes was designed in such a way so as to ensure proper lateral confinement. On completion of both the cycles, all locations were again checked for any further grout intake under pressure. Fig. 2 presents the schematic plan for piles and grout holes.

Foundation Strengthening For Residential Housing Complex

After the construction of a four storeyed housing complex in South Delhi, it was revealed that the foundations provided were of a width smaller than the designed width. The pressure on the soil exceeded the permissible value. Detailed investigations were carried out and a scheme for remedial measures was worked out to provide adequate foundation system to the structures.

Inadequacy in the foundation design was worked out for each load bearing wall and the excess load was transferred to piles on either face of the wall by using needle beams passing through the wall and connecting the pile top. The space between the needle beam and wall was filled with concrete and grouted to ensure proper load transfer of the structures to the piles through the needle beam. The load bearing walls were also reinforced with steel bars at suitable spacing so as to ensure adequate transfer of loads over the new foundation system. Fig.3 presents a schematic sketch of the foundation strengthening technique.

Settlement Cracks In Pump House

In a pretreatment plant at Bihar, part of the structures of the reservoir and pump house experienced some cracks even before the water was filled. The investigations and studies revealed that the cracks had developed due to settlement of foundations as well as due to lateral movement of soil under raft founda-

tions of the structures. The problem was studied in detail and it was proposed to stabilise and strengthen the underlying sandy soil. The scheme developed by Cengrs for arresting further settlements and cracks was based on pressure grouting technique. For this purpose, all around the structures, on the outer periphery, grout holes of 75mm dia were drilled from the existing ground level upto 6m to 10m depths as per technical requirements. A conduit pipe was placed in each of the grout holes and it was plugged at a suitable level and the mass was pressure grouted by cement slurry until refusal to grout intake was met under a steady pressure of 2.5 kg/sq.cm. The sequence of grout holes and the pressure grouting was suitably framed so as to achieve maximum extent of grouted zone. The process was repeated to ensure that the soil mass around the periphery of the structure was adequately stabilised.

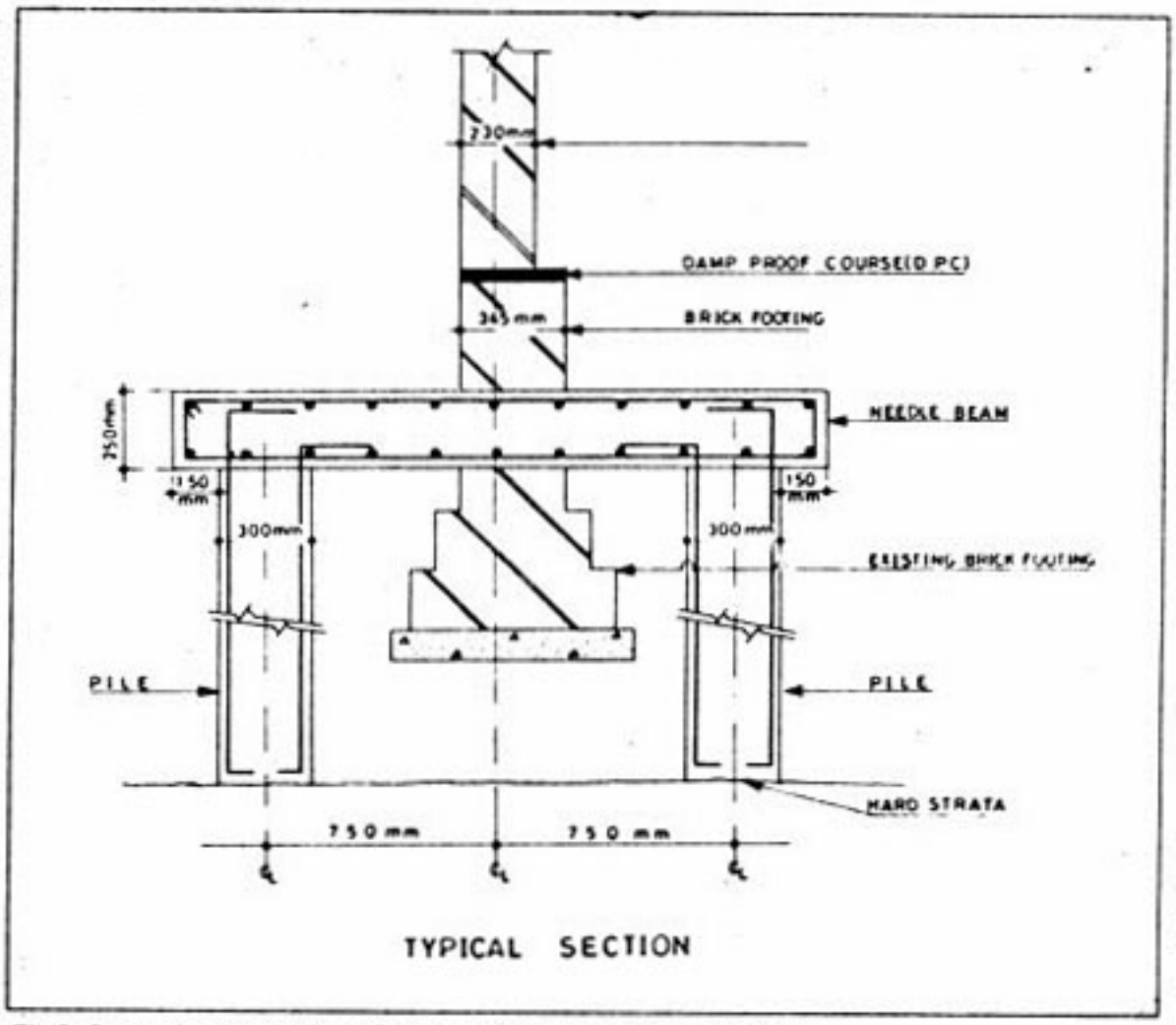

Fig 3. Strengthening Of Strip Footing Using Needle-Beam & Piles.

Settlement Cracks In Building

Stabilisation by cement grouting under a pressure of 2 kg/sq.cm was also adopted by Cengrs to arrest further foundation settlement of a three storeyed housing complex at New Delhi. Grouting was done from either side below the strip foundations upto a depth equal to twice the foundation width. Cracks in walls that had developed due to the excessive settlement were also sealed and grouted under low pressure so that the structure was fully restored. Load tests at the site confirmed the efficiency of the foundation strengthening process.

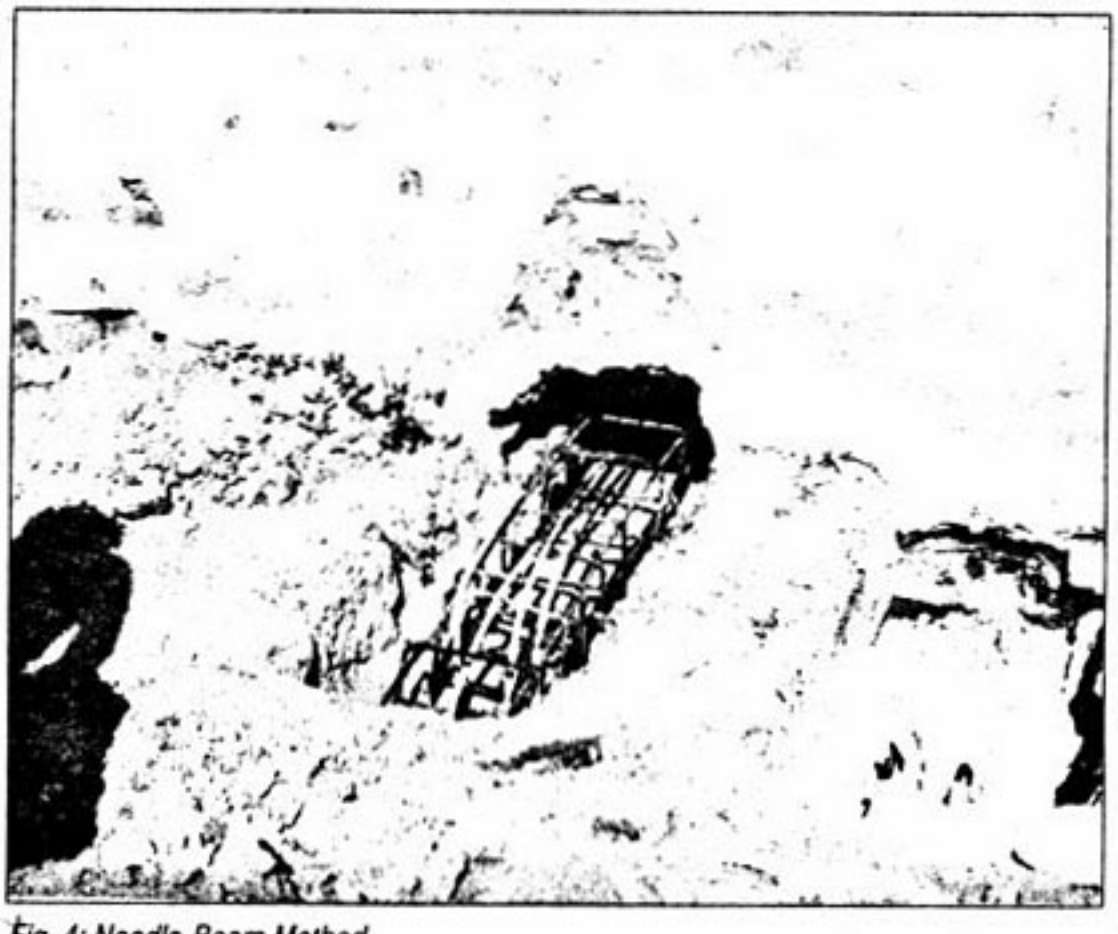

Fig. 4: Needle-Beam Method

Concluding Remarks

Pressure grouting technique has proved to be a very effective method for strengthening of foundation systems because of its flexibility in operation. It can be operated in restricted space with low headroom and can be installed easily. This technique requires proper understanding of the problem, cause of distress, sub-strata conditions etc to work out sequence of operation for desirable results. Grouting technique may need to be supplemented by other methods depending upon the problem. It may be mentioned that if this technique is adopted without proper study and analysis, it may lead to further distress/damage to structures.