ABSTRACT: Essar Steel Hazira Ltd has proposed new integrated steel plant near Hazira, Gujarat under SEZ developments and new pellet plant at Paradeep, Orissa. A construction of other structure like Jetty at Hazira is also under progress. Almost all the structures founded on driven cast in situ pile foundations at Hazira and bored cast in situ piles at Paradeep, Orissa. Quality monitoring of these thousands of piles at various locations has been carried out by pile integrity testing equipment along with static pile load tests. This paper describes some deficiency found due to construction operations which was remarkably highlighted by the pile integrity testing. As pile integrity testing has been carried out using two different instruments, this paper also describes the experience with both of the instruments.

Keywords: Pile Integrity Testing, Pile Foundation.

1. INTRODUCTION

Essar Group has established its 4.6 MTPA integrated steel plant at Hazira near Surat, Gujarat. As a part of its expansion plan Essar has proposed various facilities near the existing steel plant including extension of new Jetty and SEZ developments. Essar Group has also planned to establish its new pellet plant near Paradeep. Due to poor subsoil condition, majority of the structures are founded on the pile foundations at both the sites.

1.1 Pile/Soil Details for Hazira Plant

The generalized subsoil profile at Hazira site is presented in the Table 1. Total pile foundations proposed for these new facilities of steel plant are of around 40000.

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Thickness (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0–3</td>
<td>Filling of Silty Fine Sand</td>
</tr>
<tr>
<td>2.</td>
<td>3–7.5</td>
<td>Soft Plastic clay with silt</td>
</tr>
<tr>
<td>3.</td>
<td>7.5–16.5</td>
<td>Dense Medium to Fine silty Sand</td>
</tr>
<tr>
<td>4.</td>
<td>16.5–18.5</td>
<td>Stiff Clay with Sand &amp; Gravels</td>
</tr>
<tr>
<td>5.</td>
<td>18.5–35</td>
<td>Very Dense Med. Sand with Gravels</td>
</tr>
</tbody>
</table>

1.2 Pile/Soil Details for Paradeep Plant

Generalized subsoil profile at Paradeep site is presented in Table 2. Total pile foundations proposed for this pellet plant are around 11000.

<table>
<thead>
<tr>
<th>Layer no.</th>
<th>Thickness (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0–3</td>
<td>Fine Silty Sand (upper filling)</td>
</tr>
<tr>
<td>2.</td>
<td>3–7.5</td>
<td>Soft Plastic clay with silt</td>
</tr>
<tr>
<td>3.</td>
<td>7.5–16.5</td>
<td>Dense Medium to Fine silty Sand</td>
</tr>
<tr>
<td>4.</td>
<td>16.5–24</td>
<td>Clay with Sand and Gravels</td>
</tr>
<tr>
<td>5.</td>
<td>24–25</td>
<td>Very Dense Med. Sand with Gravels</td>
</tr>
</tbody>
</table>
For various structures it was decided to install 0.5 m to 0.6 m bored cast in situ concrete piles of 23 m to 25 m length using drilling mud technique.

2. QA/QC FOR INSTALLED PILE

QA/QC for pile foundations is carried out by performing Pile Load Tests along with Pile Integrity Testing. For Pile Integrity Testing, Essar Construction has purchased PET (Pile Echo Tester) from Piletest.com Ltd., UK for Hazira site and PIT-W (Pile Integrity Tester) from Pile Dynamics Inc., for Paradeep site. Integrity testing was carried out on larger number of piles as a part of quality assurance program to maintain highest standard of quality along with faster construction progress. The instruments used are shown in Figures 1 and 2.

3. OBSERVATIONS AT HAZIRA SITE

The observations of pile integrity testing were recorded regularly. It has been observed that some specific locations at the project site showed defects based on the reflectograms obtained from PIT tests. Few representative recordings are presented in Figure 3a and 3b.

Piles at specific locations, particularly near water tank showed similar findings as shown in Figure 3. It was also seen from the records that piles showed tendency to have necking at a depth varying from 3 to 7 m below ground level. Wherever possible the piles were exposed to confirm the findings of PET. It was than decided to test almost all piles in that area for its integrity. Figure 4 shows the exposed foundations showing defects. Piles that showed defects up to 7.0 m were routinely exposed and rebuilt before use in construction.

4. INTROSPECTION FOR DEFECTS OBSERVED

In order to investigate the cause of problem, the pile driving process was modelled using well known finite element software using 15 node axi-symmetric mesh. The behaviour of sand was modelled by means of the undrained hardening soil model and for clay Mohr-Coulomb undrained behaviour was assumed. The pile was modelled by means of the linear elastic model considering non-porous behaviour. Standard absorbent boundaries were used at the bottom and at the side boundary to avoid spurious reflection of the waves generated during driving.
From the study it was found that the generation of the excess pore water pressure cause problems for the freshly placed piles in the vicinity (Fig. 5). As the driven piles installed are of displacement piles, the radial pressures exerted due to soil displacement along with the excess pore pressure generated as the water table is at 2 m from GL. This has caused serious defects on the freshly placed concrete piles. The excess pore pressure was estimated from the finite element model and found in the range of 137 KN/m² (Fig. 6). This range of pore pressure has resulted in serious defects of necking at various locations in the freshly installed concrete piles (i.e. 2 to 6 m from GL).

To overcome the problem, pile driving schedule was modified. The spacing between two consecutive pile installations was increased with slower installation rate. Thereafter the pile showed no construction defect and the same was verified by Pile Integrity Tests. Thus, the construction problem was solved successfully by changing the construction sequence of piles.

5. OBSERVATIONS FOR JETTY PILES

In Jetty area, piles are of 1m to 1.2 m diameter with length around 35 m. Test record had shown some defect around 21 m in the jetty pile (Figure 7). It was decided to take another opinion for same to countermeasure the problem. The output from the other consultant was also showing same sign of necking at 21 m depth (Figure 8). From both the record it was concluded that there is a necking at 21 m from the ground level. As there is a major defect in the pile, Essar Construction had decided to reject the pile and install new pile in the vicinity. Thus, low strain Pile Integrity testing has been again proved much useful tool for QA/QC of pile constructions.
6. OBSERVATIONS AT PARADEEP SITE

At the start of the job, Essar Constructions did not have any integrity instrument at Paradeep and hence, QA/QC was mostly in the form of Pile load test (Vertical and Lateral). A local testing company engaged at the testing site provided integrity data and also reported defect in the piles. Surprisingly, they also commented that these defects can be ignored and piles can be accepted due to group action. Typically each group consisted of 4-6 piles and 2-3 piles were classified as defective in each group. Ignoring three defective piles in the group of four piles can result serious problem for the stability of structures. As a confirmation, it was decided to test the piles classified as defect. All the piles reported satisfactory results for the tests conducted as per codal provisions. It was later noticed that data collection and interpretation of the local testing company was very poor and sub-standard. The reflectograms shown in Figure: 9a and 9b is self explanatory. Immediate after this, pile load test frequency had been increased and decided to test “piles in doubt” for its load capacity. Almost all the load tests were found satisfactory as per the codal provisions.

![Fig. 9: Record Received from Consultant at Paradeep](image)

7. EXPERIENCES WITH INSTRUMENTS

To verify the output from both the instruments, testing was carried out on same piles using both the instruments at Paradeep (Figures 11 & 12). It is found that the reflectograms were similar, although data clarity and post processing was better with PIT-W. The PIT-W also offered advantage of PROFILE; it provides pile shape and easier interpretation for an engineer not experienced in studying integrity test graphs.

![Fig. 11: PET output for Paradeep Pile No FB-A7](image)

PET has smart trigger option which has algorithm to choose best suited number of blows which gives flexibility to user during the recordings. It has also option to sense and prefix the noise/local vibration so that during the recordings it will be eliminated from the main record. Both the instruments are very handy and useful and correctly record the reflectograms. Interpretation is easy in PIT-W as it comes with the option of profile plotting. Even with the profile plotting option, judgement needs experience and great skills. Figure 12 shows the pile profile based on the velocity time reflectogram.
2. Low Strain Pile Integrity Testing is simple, reliable and can be quickly performed to locate piles with major or serious defects.

3. However, it needs to be ensured that the engineer/technician operating the equipment is adequately trained to collect proper data. Also that the testing agency has adequate knowledge about wave mechanics, pile installation and soil and merely owning equipment does not imply proper testing at project sites.

4. Incorrect and poor data collection and interpretation may lead to delays, confusion and extra costs at the project site and hence emphasis must be laid that the engineer for testing has adequate skills for the job.

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REFERENCES

