Cement Grouting: An Alternative Ground Improvement Technique for Municipal Waste Dump Site

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Abstract: Because of the population explosion municipal solid waste generation is increasing day by day in India. Urbanization is the physical growth of urban areas as a result of global change. The facilities like education, healthcare system, employment avenues, civic facilities and social welfare are reasons attracting people to urban areas. Land cost is very high in urban centres and at the same time decreasing availability of good construction site is building up pressure on the engineers to utilize even the poorest site either by providing special type of foundation or by improving ground in urban centres. In this context literature is reviewed for use of landfill site for housing. The site exploration for old dump site was carried out to assess subsoil characteristics. The objective was to evolve strategy for economical feasible ground improvement technique to obtain permissible bearing capacity of 150 kPa and settlement not more than 50 mm. The exploration of site was done by Dynamic cone Penetration Test (DCPT) to find the bearing capacity. The site can be used for construction of low rise housing for rehabilitation of displaced persons under Town Planning (TP) scheme within city area utilizing old landfill sites.

Key words: Municipal solid waste · Low pressure cement grouting · Dynamic cone penetration test · Bearing capacity

INTRODUCTION

India is facing two fold problems, population explosion and rapid industrialization. Urbanization is the physical growth of urban areas as a result of industrialization. The facilities like education, healthcare systems, employment avenues, civic facilities and social welfare are reasons attracting people to urban areas. Because of the population explosion the generation rate of municipal solid waste is increasing day by day. Table 1 shows that the urban population is increased by 41% of the total population by year 2010 which only 17.3% in the year of 1991.

Table 2 shows the data for the mega cities in India. The disposal of municipal solid waste by means of landfilling is the economical alternative as the other method like incineration is not the cost effective one. Disposal of waste by landfilling requires huge area within the city to minimize the transportation cost of the waste to the final disposal site.

As the land cost is increasing tremendously and decreasing availability of good construction site is building up pressure on the engineers to utilize even the poorest site either by providing special type of foundation or by improving ground. The weak subsoil deposits pose the problems of low bearing capacity and excessive settlement over long period of time. This may be overcome by the recently developed method of ground improvement. It can be effectively utilized to force the soil to behave according to the project requirement rather than having to change the project to meet the limitation due to weak ground.

As the old and closed landfills are having the limited end use in terms of recreational uses like gardens and golf courses, it is now the demand of time to gain some return from the old landfills like infrastructure, commercial and low income residential development.

Cost of land in Surat city has increased tremendously in last decade. To satisfy need of land Surat city limits has been expanded and more area is included by Surat Municipal Corporation (SMC). SMC is planning to make the city zero slum in upcoming coming years. For that, slum rehabilitation policy is prepared by SMC. For the same purpose large area is required within city limit. If landfill area can be used for the purpose it may be the economical solution.

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Table 1: Trends of Urbanization.

<table>
<thead>
<tr>
<th>Description</th>
<th>Year 1951</th>
<th>Year 1991</th>
<th>Year 2001</th>
<th>Year 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Urban Agglomerations / Towns</td>
<td>2795</td>
<td>3768</td>
<td>5161</td>
<td>-</td>
</tr>
<tr>
<td>Urban Population (in Millions)</td>
<td>62</td>
<td>217</td>
<td>285</td>
<td>550</td>
</tr>
<tr>
<td>As percentage of total Population</td>
<td>17.30%</td>
<td>25.72%</td>
<td>27.80%</td>
<td>41%</td>
</tr>
</tbody>
</table>

Table 2: The Waste composition in four mega cities in India

<table>
<thead>
<tr>
<th>Description</th>
<th>Delhi</th>
<th>Mumbai</th>
<th>Chennai</th>
<th>Kolkata</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population [Million]</td>
<td>10</td>
<td>13.8</td>
<td>5.8</td>
<td>12</td>
</tr>
<tr>
<td>MSW [tons/day]</td>
<td>5000</td>
<td>7600</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Waste Composition Paper [%]</td>
<td>5.57</td>
<td>7.7</td>
<td>4.84</td>
<td>3.18</td>
</tr>
<tr>
<td>Plastic + Metal + Glass &amp; Crockery [%]</td>
<td>7.25</td>
<td>7.67</td>
<td>5.54</td>
<td>5.23</td>
</tr>
<tr>
<td>Biodegradable [%]</td>
<td>38.6</td>
<td>39.09</td>
<td>57.24</td>
<td>41.24</td>
</tr>
<tr>
<td>Bioreistant [%]</td>
<td>13.87</td>
<td>9.24</td>
<td>10.9</td>
<td>16.77</td>
</tr>
<tr>
<td>Inert material [%]</td>
<td>34.71</td>
<td>39.09</td>
<td>57.24</td>
<td>41.24</td>
</tr>
</tbody>
</table>

Textiles/Polythene bags, Leather, Rubber, Synthetic material, etc.,

In this context literature is reviewed for use of landfill site for housing. The site exploration for old dump site was carried out to assess subsoil characteristics. The objective was to evolve strategy for economical feasible ground improvement technique to obtain permissible bearing capacity. The exploration of site was done by DCPT to find the bearing capacity.

**Literature Review:** Rolling dynamic compaction over the refuse filled area was controlled by surface settlement monitoring. Effective refusal was determined in this case by averaging the measured settlements over the whole area and observing the rate of increase on a plot of impact roller passes versus average settlement [1].

Ground improvement using the rolling dynamic compaction (RDC) method has proven to be successful for residential development overlying an old waste tip. A constant surface wave system was used to monitor the compaction effectiveness. Shear wave velocity measurements were taken to evaluate the waste material stiffness parameters before and after the dynamic compaction process. This allows the assessment of the degree of improvement achieved on site with the use of RDC [2].

Dynamic Consolidation is also the ground improvement technique used for the landfill sites. This method is used to reduce void space, increase density and reduce long term settlement of the fill. By increasing the density, it increases the storage capacity of the landfill and increases the bearing capacity of the same. With reducing the long term settlement, roads, parking bays and lighter structures can be designed on shallow foundations on closed landfills [3].

It is a challenging job for the engineers to design a structure on closed landfill based on settlement condition and to determine the suitable foundation. Pile load tests and plate load tests should be conducted as per the site requirements [4].

Before carrying any construction work on MSW landfill, site improvement must be done, for that compressibility and low bearing capacity of the waste material underlying the construction must be taken into consideration. To provide sufficient bearing capacity, pile foundations are typically used. Downdrag on the piles due to waste settlement is a major problem [6]. Due to the large settlement potential landfill redevelopment using shallow foundations is generally restricted to low rise structures of one or two stories with raft foundations. A relatively new form of ground densification known as rolling dynamic compaction has been used to redevelop an old waste tip site. Rolling dynamic compaction was accomplished using 8t non circular (4 sided or square) impact module towed in a frame by a 4-wheel drive tractor, a technique utilized for various applications around Australia for more than 20 years.

The dynamic cone penetration test (DCPT) was carried out on open waste dump site as this test is very simple and quick and other method like SPT is not suitable because drilling is very difficult on site. This paper will describe the DCPT tests carried out on Bharat Open Waste Dump site.

**Waste Disposal Site at Surat:** Daily 1,100 metric tonnes of municipal solid waste from 326.515 km² of Surat city is collected and disposed at landfill site. In Surat, there are two dump sites as follows,
Landfill site at Khajod.
- Open Waste Dump site at Bhatar.

**Landfill Site at Khajod:** Currently, Municipal solid waste is collected from city and carried to various transfer stations. From these transfer stations the waste is disposed to Final disposal site at Khajod. The Site is located on Sachin Magdalla Road at about 15 Km away from city. The area of Final disposal at Khajod site is about 2 Km². Authorization of site for disposal purpose is granted by Gujarat Pollution Control Board (GPCB). It is the only landfill site which is currently in operation phase.

**Open Waste Dump Site at Bhatar:** Another landfill site in Surat city is Bhatar landfill site at Bhatar, near Sewage Treatment Plant. The land fill site is on a bank of Mithkhadi from Bamroli Road-Hegdevar Bridge to Althan-Bamroli road Bridge. The land is filled by garbage of various depth of 1.00m to 5.00m at various lengths of bank. This site is discontinued since 2002. Bhatar site was found convenient for the proposed experimental work as the site is closed.

The site is filled by biodegradable as well as non biodegradable garbage at the right bank of Mithkhadi between Bamroli Road-Hegdevar Bridge to Althan-Bamroli road bridge. The filled bank is approximately 3.00 km length in varying width of 10m to 1000m. The size of landfill area for waste placement is approximately 0.23 Km². Waste placed in site is approximated at 35,45,040 MT, with depth varying from 1 m to 5.0 m. Filling in the site had began in 1991 and it was closed since 24th January - 2002.

The landfill’s different ingredients were the major reasons for its complex engineering properties. Table 3 gives typical composition of random sample of solid waste from Bhatar dump site.

Table 3 shows the moisture present at the site is 18.5 %. The pH value of fill material at site is 8.12 which exceed the value of 7.0 which indicates that the chemical reaction occurred under alkline condition and the intensity of the reaction depended on the changes of temperature. As dumping at the site was discontinued since 2002, compositions of the site do not show any biodegradable materials. All the dumped organic material is decomposed by the time. The dump site is subjected to a range of temperature from 25° to 40°C depending on a season of the year. Dirt stones and sand size grains present in large proportion (42.5 %) in composition. The site content 12.5 % clothes and fabrics. Plastic (threads) present at the site is 5 % whereas Plastic (polyethylene) is 12.5 %. Metal content at the site is also high, which is 25 %. Glass present at the site is 2.5 %.

**Dynamic Cone Penetration Test:** The Dynamic cone penetration test (DCPT) is a quick test to set up and run. This test has been conducted by driving the cone by blows of hammer. The number of blows for driving the cone through a specified distance was a measure of the dynamic cone resistance. DCPT has been conducted as per (IS: 4968 - Part I - 1976, reaffirmed 1997).

A dynamic cone test has been performed by using a 50 mm core without bentonite slurry. The number of blows for every 10 cm penetration was recorded. The number of blows required for 30 cm of penetration was taken as the dynamic cone resistance. The method adopted to improve open waste dump site properties was low pressure cement grout. A hole of 5 cm having 6m depth was grouted with low pressure cement grout.

The cement grout used was having proportion 1:10. After a period of one week Dynamic Cone Penetration Test was carried out at 450 mm away from the hole to check the improvement in the geotechnical properties of landfill. Two Dynamic cone penetration tests were carried out on either sides of hole.

Bearing capacity of the site before treatment from Dynamic Cone Penetration value (Nc) Dynamic cone penetration value at 2.1 m depth from result of DCPT given in Figure 1.

\[ N_c = 9 \text{ as the depth of footing } = 2.1 \text{ m}, \]

For \( \Theta_o=0 \), soil: Saturated clay [5]
\[ C_t = 8 N_c = 72 \text{ kPa} \]

According to IS 6403-1981 the Safe Bearing Capacity will be 216 kPa.

Applying water table correction, taking factor of submergence 2,

Safe Bearing Capacity = 108 kPa

Bearing capacity of site after treatment of grouting from Dynamic Cone Penetration value (Nc)

Dynamic cone penetration value at 2.1 m depth from result of DCPT given in Figure 1.

\[ N_c = 14 \text{ as the depth of footing } = 2.1 \text{ m}, \]

For \( \Theta_o=0 \), soil: Saturated clay [5]
\[ C_t = 8 N_c = 112 \text{ kPa} \]
According to IS 6403-1981 the Safe Bearing Capacity will be 336 kPa.

Applying water table correction, taking factor of submergence 2,

Safe Bearing Capacity = 168 kPa

The DCPT test on open waste dump site gives the bearing capacity of 108 kPa, which is increased by 55% after application of low pressure grouting i.e. Safe Bearing Capacity will be 168 kPa. The grouted depth could have net Safe Bearing Capacity of 168 kPa even after flooding.

CONCLUSION

From the experimental work it is found that the waste fill material is heterogeneous in nature with variations in various geotechnical properties and varies from site to site. Study aimed to establish that various ground improvement techniques are feasible for old waste dump sites. After application of ground improvement technique, the waste fill can safely take pressure of footings of Ground + 4 storey building of economical weaker section (EWS). The clearance of environment aspect is assumed. Low pressure grout judged by DCPT after a week, has given good in improvement. Detailed study is required for particular site and cost effectiveness of techniques and material shall be checked for a final economical solution. Field pilot quick exploration by Dynamic Cone Penetration Test has proved feasibility of use of landfill old plot (area 23 hectare). It can be considered for low cost hosing schemes for EWS and demolished labour colonies within the city.

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REFERENCES


