Soil Strengthening By Using Cement And Binders For Concrete Constructions at Mudar Al-Janabi, s school in Kufa

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Abstract. There are many methods and devices needed to stabilize the ground, and the commonly used method around the world is to inject soil (cement and additives) in the spaces inside the structure, or to displace liquids and gases of within it. The benefit of this method lies in its economic feasibility by reducing the high costs of the soil replacement process and reducing the risk of collapse of some existing buildings, due to irregular subsidence of the structure. There are many factors that cause the irregular subsidence, such as: high groundwater, degree of acidity, percentage of organic materials, percentage of salts and the composition and components of the soil. More important than that is the building’s load on the soil for existing buildings. Therefore, it is good to inject the soil with soil stabilizing chemicals under the foundations at specific locations depending on the type of project. These materials form a secondary foundation under the original foundation of the building. It helps stabilize the building and resists changes in the soil that cause collapses. Choosing the correct method for deep soil stabilization depends on several conditions such as the type and alternative layers of soil, loading volume, location and type of project and other things. In this research, the latest methods of soil treatment, especially gypsum soil, and the techniques necessary for it using sodium silicate as binder were reviewed and studied. Soil was injected into the Mudar Al-Janabi School, and the cost of this school amounted to more than one and a half billion Iraqi dinars. It was in danger of collapsing because its soil was gypsum, and recommendations were made to demolish it. In terms of economic feasibility, the soil was treated after careful technical and advisory evaluation at a total cost that did not exceed 10 million Iraqi dinars. The injection showed satisfactory results through our follow-up for a year by reducing the collapse of the building through a decrease in the width of the shear cracks in the building walls by 50% and 100% after six months of the first and second phase of the injection, respectively.

1 Introduction

In general, grouting is used to fill voids in soil such as cracks and porous structures in order to increase resistance against deformation,

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to provide shear strength, cohesion and uniaxial compressive strength or finally to reduce
the interconnected porosity and conductivity of the aquifer (Moseley and Kirsch, 2004). The
process of soil filling has become one of the global and basic methods for treating soil under
buildings by studying the properties of the soil according to its influence on environmental
variables (Burke and G. K, 2004). Areas with poor soil are considered one of the major
problems facing engineers, especially in infrastructure (Saleh. et al, 2019). The urgent need
to develop and remediate infrastructure has become an important factor due to population
development, which forces communities to find alternative ways of demolishing and
rebuilding the old facility (Archibong.et al, 2020). Binders as an additive to agglomerated
materials that creates bonding strength in the final product (Engleitner,1990)Soil injection
can be divided into: permeate injection, pressure injection, and soil fracturing injection, flow
injection, rock injection and deep injection and mixing method (Kazemian. et al, 2009).

2 Injection materials

Depending on the area to be injected, type of soil or rock, etc., different materials can be
used for injection. However, the basic method is the same: the soil or rock is injected with a
liquid filler that sets and softens or works as a sealant on the material permeability.

2.1. Cement grouting

High permeability materials are injected by cement (or cement plaster). Cement and water
or a mixture of four parts sand to one part cement is the usual composition.

2.2. Bentonite grouting

Bentonite forms a very water-resistant gel because it is made from clay that has
thixotropic characteristics that it can make an enduring barrier to flow of water when it is
mixed with additives. This method is often used to combat soil seepage in alluvial soils under
foundations of dams or other water-related structures and where soil particles are too small
for cement injection.

2.3. Chemical grouting

For medium to coarse grade soil, chemical injection is used; materials such as calcium
chloride and sodium silicate are mixed together in liquid form and hardened to a gel. First,
the pipes are routed into the ground and then a chemical is injected.

In other words, the reaction and strengthening of the soil is rapid. The other process:
includes chemical mixing before injection with delayed hardening of the composition.
Chemical injection has the advantages of allowing economical well drilling spacing, greater
grout penetration, and greater flexibility regarding injection time.

2.4. Resin grouting.

Unlike chemical injection, resin injection has a too low viscosity that can permeate fine
sand. Depending on the chemical content of groundwater, the type of resin is used. Common
types involve tannin-based fillers, phenol formaldehyde and resorcinol formaldehyde.
2.5. Bituminous grouting

As a water impermeable barrier for fine sand, bitumen emulsion can be used as a suitable injection material. This type of grouting will not increase soil resistance, but can effectively form break walls beneath levees and other water-related structures.

3 Injection methods

There are many injection methods were explained below depend on the types of failure of the structure and the type of soil that were shown as a schematic diagram in Figure (1)

3.1 Permeation grouting

This grouting method is used to fill pores in soil, joints, or cracks in rocks with grout without disturbing its composition. Permeation grouting refers to replacing water in the spaces between the particles of soil with a grout fluid at low injection pressure to avoid the fracturing (Manfred, 1990). Generally, it is used to decrease soil permeability and control aquifer flow, it also can be used to stiffen and strengthen the ground (CRIA, 2000).

3.2 Compaction grouting

The filling mixture in this method is especially designed so that it does not penetrate the voids of soil or mix with the soil but it displaces the soil into that it is injected. In granular sediments that are not of maximum density, the size of voids is decrease and the sediments are densified (Reuben, 2003). In this method a very hard mortar (e.g. 25 mm slump) is injected into the soft soil, forming grout follicles that displace and densify the surrounding ground, without penetrating the pores of the soil (Manfred, 1990).

3.3 Hydro fracture grouting

Hydro fracturing grouting is the intentional crushing of rock or soil using grouting under pressure. It is usually used to stiffen and compact the ground or arrival inaccessible voids in other way, which reduces the mass permeability of the ground and results in structural uplift (CRIA, 2000). The mass of soil may split with increasing grouting pressure sufficiently and synthetic grout filled cracks are formed. In rocks, existing cracks may expand and new fracture may occur. French engineers also refer to this as claquage (Cambefort, 1977).

3.4 Jet grouting

The ground is physically destroyed by high-pressure water or grout, in the process modify, and thus improve it. In normal procedure, the string of drill is advanced to the desired depth and then the high-pressure water or grout is inserted while pulling the rods (Moseley and Kirsch, 2004). This method requires high speed, 28 to 42 MPa of pressure. This works to shear the soil hydraulically and mixes the cement filler or suitable binder to form a column or column of cement soil with the appropriate soil and binder.
3.5 Rock grouting

Rock grouting is the total or partial filling by injection the grout into cracks, joints or fractures in a rock mass with grout and avoiding creating new fractures or opening existing fractures, in order to increase the stiffness and reduce the permeability of the grouted mass (CRIA, 2000).

3.6 Compensation Grouting

Compensation grouting is the reacting use of permeation, compaction or hydro fracture grouting as an interposition between an existent structure and an engineering process (especially tunneling). The purpose is to reduce ground movement that may affect the existing structure (CRIA, 2000).

3.7 Deep Mixing Methods

Today in all over the world, as a soil improvement method, the deep mixing method is accepted which is implemented to improve the deformation properties, the strength and permeability of the soil. This method based on mixture binders, such as cement, fly ash, lime and other additives, with the soil by using the rotating mixing tools so as to form hardening material columns where pozzolanic reactions are developed between the soil grains and the binder (Costas and Maria, 2008).

![Fig. 1. schematic diagram of the injection methods.](image_url)
4 Assess the condition of the soil by investigating and monitoring the subsidence occurring in the building of Mudar Al-Janabi Secondary School

In this research, the irregular subsidence of the school, that costed more than one and a half billion Iraqi dinars, was studied and was at risk of collapse a year after final receipt, the shear cracks were very deep due to soil subsidence, and previous recommendations were intended to demolish it. After evaluating the structure and conducting the necessary soil investigations, it was found that the cause of the subsidence was the presence of cavitation in soil at depths of 3 m or more due to the gypsum present in it, because the structure was implemented without conducting soil investigations. In addition, groundwater was withdrawn due to sewage works in the near area. The building was monitored for a full year to monitor the cracks in the walls that was measured by demic point, where the distance is measured randomly between the two points defined by a horizontal line as shown in Figure (2). After a few months, the distance increased due to the increased width of the cracks, the cracks increased to a width about 1 mm or parts of it during three months as readings were recorded in Table No. (1).

![Image of cracks](image.png)

**Fig. 2. Demic points**

**Table 1. Recorded readings for test points**

<table>
<thead>
<tr>
<th>Points</th>
<th>Initial reading (mm)</th>
<th>3 months</th>
<th>6 months</th>
<th>9 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.26</td>
<td>3.32</td>
<td>3.405</td>
<td>3.51</td>
<td>3.6</td>
</tr>
<tr>
<td>B</td>
<td>4.41</td>
<td>4.49</td>
<td>4.56</td>
<td>4.62</td>
<td>4.77</td>
</tr>
<tr>
<td>C</td>
<td>5.94</td>
<td>5.96</td>
<td>5.98</td>
<td>6.1</td>
<td>7.12</td>
</tr>
</tbody>
</table>
5 Injection mechanism

The soil was treated by injecting it with cement and sodium silicate in two stages, between the first stage and second one are six months. The cracks width was monitored, as they began to decrease in the first stage of injection. After 6 months, the cracks width decreased more and there was stability in them as shown in Table No. (2), where, the optimal reading was at point G&A because the difference between the two readings during three months is zero. Excavation is done next to the foundations using a special drilling machine at a depth of 6 meters underground and according to the special injection points determined by the Structural Evaluation Committee. After that, water and cement are mixed in a ratio of (1:4) and then sodium silicate is added as a binder. The mixture or grout is injected through pipes more than 6 meters long and with openings along their length to facilitate the flow of grout into the soil. These pipes are inserted into the soil at an angle of 45° under a pressure not exceeding seven bar. Figures No. (3), (4) and (5) show the injection mechanism of Mudar Al-Janabi Secondary School.

<table>
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<tbody>
<tr>
<td>A</td>
<td>3.6</td>
<td>3.63</td>
<td>3.63</td>
</tr>
<tr>
<td>B</td>
<td>4.77</td>
<td>4.81</td>
<td>4.82</td>
</tr>
<tr>
<td>C</td>
<td>7.12</td>
<td>7.55</td>
<td>7.58</td>
</tr>
<tr>
<td>G</td>
<td>4.56</td>
<td>4.62</td>
<td>4.62</td>
</tr>
</tbody>
</table>
Fig. 3. Drilling injection points

Fig. 4. Filling injection using galvanized tubes
6 Conclusion

Through periodic follow-ups and recording readings of cracks width occurring in the walls, an indication was given to the researcher of the extent to which the soil was affected by the rise and fall of groundwater and the increase in cavitation. As well as the presence of some chemical substances, seeping into the soil under the foundations due to the sewage works conducted in the area and the extent of their impact on. The interaction and the creation of cavities led to a reduction in soil resistance. Through field investigations, some structurally hazardous gypsum materials were found. The mechanism and method of injection used were successful, as there was a stability in the thickness of the crack after 6 months of injection. Therefore, choosing grouting and using this method is considered one of the successful solutions in school buildings to avoid demolition of the structure. In addition to economic feasibility, the soil was treated after a careful technical and advisory evaluation with very low cost compared to other treatments. The evaluation shall be carried out through field research of the type of soil and the amount of subsidence, which is considered an indication of the level of resistance of this soil. The life span of the structure has improved as the structure has stabilized until today after more than five years after injection.

References