GeoDrilling International

ESTABLISHED 1993

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ISSN 0969-3769

May 2014 www.geodrillinginternational.com

Third-generation polymers

Soil-stabilisation specialist Ground Engineering Operations' (GEO's) G3 polymer system has been used as an alternative to bentonite slurry in deep-foundation projects for the Delhi Metro

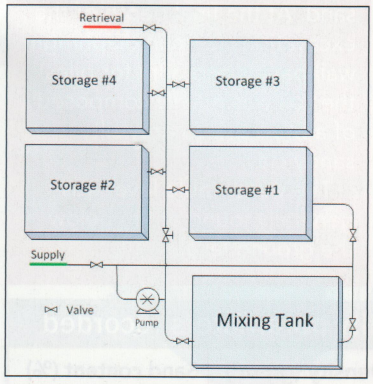
The Delhi Metro railway network, which began operations in 2002, has 143 active stations and 189.7km of track. Equipped with state-of-the-art technologies, it already serves as a reference point for other metro projects in India and the south Asia region.

Delhi Metro Railway Company (DMRC) is currently undertaking its third phase of network expansion that is expected to be completed by 2021.

Due to the restrictions imposed by the urban location of these projects, including constrained space and logistics and the need for environmental disposal of excavated soil and drilling fluids, the clients chose GEO's G3 polymer system for soil stabilisation. The stabilisation fluid has been used in the execution of piles and diaphragm wall (D-wall) in diverse locations within the city.

GEO was responsible for supplying the products and technical support in the use of the G3 system and its Polymud slurry in collaboration with several Indian foundation companies, including Larsen & Toubro GeoStructure, ITD Cementation, Valecha Engineering, LRS Kamar Infra, Vijay Nirman Construction (VNC) and RV Akash Ganga (RVAG).

Mixing polymer for stabilisation



Simplified schematic of a polymer-batching plant

VIOLET LINE WORK

Phase III of the network expansion is composed of 28 metro stations with a total of 500,000m² of diaphragm wall. Each station has approximately 18,000m² of panels. The stations also involve the execution of piles for slab support.

At the Mandi House and Janpath Road stations on the Violet Line, only the G3 system was used for soil stabilisation. The foundation companies involved in these projects were: LRS Kamar Infra at Mandi House; and VNC and RVAG at Janpath Road station. At these stations ▸

Metro station construction site at Janpath Road

Map of DMRC's Violet Line third-phase extension (dotted)

Equipment

The foundation works at Mandi House station were undertaken with two MAIT HR180 rigs, one for piling and the other adapted for diaphragm-wall excavation. To support the operations, two cranes were also used, with 15t and 40t of maximum load capacity respectively.

Pile boring was conducted with auger and drilling-bucket tools 1,000mm in diameter. To allow verticality and top-soil support, a guide casing of 1,100mm diameter and 3m length was used.

Diaphragm wall panels were installed with a hydraulic grab of 800mm width and 2,800mm length. Every panel was excavated in three phases.

For the Janpath Road station development, VNC used one diaphragm-wall excavation rig, a Soilmec SR30, with two auxiliary cranes (max. load of 16t and 35t respectively); and a hydraulic grab with 800mm width and 2,800mm length. RV Akash Ganga, in turn, had one BAUER BG 34 pile-drilling rig and one MAIT HR130 diaphragm-wall excavation rig; a 1,000mm-diameter auger and drilling bucket, guiding casing of 1,100mm diameter and 3m length; hydraulic grab with 800mm width and 2800mm length; plus two auxiliary cranes of 20t and 35t maximum load capacity.

Top row: different stages in piling and construction of diaphragm wall, concluding with the completed, exposed D-wall at Janpath Road station

the standard panel of diaphragm wall was 800mm in width, 3 to 6m long and 23m deep.

The piles were executed by RVAG at Janpath Road station and by LRS Kamar at Mandi House. Each pile was 1m in diameter with an average depth of 33m.

The piles were casted to a depth of 18-14m and an 'H' steel beam was installed in the middle of the fresh concrete to reach the ground-water level, then the remaining space (volume of pile) was filled with sand to the surface.

STABILISATION FLUID

The G3 system, based on the granular synthetic polymer Polymud, was selected for DMRC's foundation works as it does not pose the same environmental risks that are associated with bentonite.

Polymud is a highly concentrated polymer and has been specifically designed to interact chemically with different types of soil (after being properly hydrated/mixed with water). With high molecular weight, it generates a high-viscosity slurry that is suitable for provisional soil stabilisation of deep foundations and other geotechnical applications.

Koden test equipment in use on one section of D-wall, and (below) the printout result from the test

The other products that make up the G3 system have been developed to interact directly with the main polymer (Polymud) in a way that improves certain slurry features in more demanding situations.

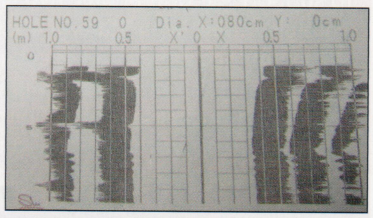
To prepare the stabilisation fluid (slurry), the granular polymer is added to a constant flow of water (close-circuit circulation) in a tank.

In some of DMRC's projects, Polymud has been the only product used for soil stabilisation of deep foundations (piles and D-wall).

The slurry prepared with Polymud, water and pH adjuster (to increase the water pH to 12) has revealed good results in soil stabilisation and slurry cleanliness, without requiring the use of any other kind of additives. Its soil-stabilisation efficiency has been proven by keeping completed diaphragm wall panels open for seven days without any record of collapses and with a final concrete overbreak (consumption) under 10%.

POLYMER-BATCHING PLANT

The foundations all had a different set-up for their polymer-batching plant, but the general concept was the same.



Tanks are used for slurry storage, the number and volume capacity of these tanks dependant on the production volume, with at least one of them adapted/prepared for slurry mixing.

It is usual to have at least one sedimentation tank available for the G3 system. This tank, located between the retrieval line and the storage tanks, allows the fine soil particles that are retrieved with the slurry to settle, avoiding accumulation of solids in the storage tanks.

Soil characterisation

The geological strata of the two station sites were quite similar.

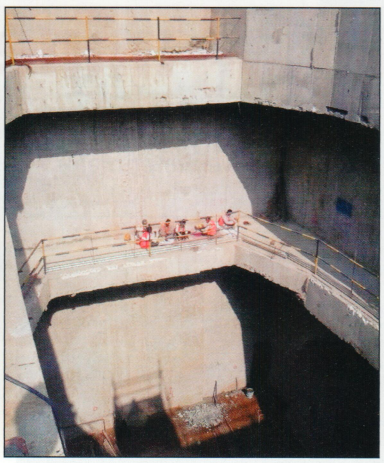
A landfill cover with maximum depth of 3m, followed by a brownish sandy silt to 12m that was having some intercalations of more sandy soil.

Below 12m this silt starts to have some amount of clay between the intercalations of sand. At the final depth of the excavations (23m in diaphragm wall panels and 33m for piles) the soil was mainly composed of a brownish to grey silty-sandy clay.

The water table level was generally found at 9m below the ground level.

Table 1: polymer slurry quality parameters recorded

Viscosity	pH	Density (g/cm^3)	Sand content (%)
55-65	10-12	1.00-1.02	0-0.5



In this particular case, for the three foundation contactors, the slurry retrieved lacked any fine soil particles and the sedimentation tank was not required.

STABLE AND CLEAN

In all the executed excavations, where the slurry level was kept to the guide wall (never below 1.5m in depth) and inside the guide casing (never below 3m), no collapse was recorded. All the excavations were carried out without problems and some remained open for seven days.

The stabilisation capacity of the slurry was proven by the Koden test (which verifies verticality), which was performed in all the sections of diaphragm wall at all DMRC sites.

The average concrete over-break records were 11% for diaphragm-wall panels and 3% for piles. The polymer slurry quality parameters were also frequently controlled and their average values are presented in Table 1.

In the diaphragm wall panels and the piles, the sand content measured on the excavation toe was much reduced (in some cases even nil), hence proving the cleaning efficiency of Polymud slurry in the silty soils of New Delhi and revealing time savings when compared with the desanding process required when the traditional bentonite slurry is used.

None of the stations using the G3 system required any repair works after the diaphragm wall was exposed.

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This article was written by Eonio Trindade, technical manager at GEO