A CASE ON ENGINEERED SOLUTION FOR DEEP EXCAVATION IN RESTRICTED SPACE

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Abstract : This paper discusses the methodology adopted in soil support for deep excavation carried out for installation of press foundation in live working mechanical shop with space restriction and variable soil conditions. The method adopted was cheapest of available alternatives.

Keywords : Soil, Stability, Grouting, Excavation, Foundation.

1. Introduction

1.1 Plant and Work Description

Mahindra Vehicle Manufacturers Ltd. has its vehicle manufacturing facility located at Chaken near Pune. The manufacturing facility is spread over 700 acre land with number of manufacturing shops and other facilities.
The existing Press Shop facility was constructed and put to operation in the year 2010 with four Press installed at a place. A Press is a heavy and huge automatic equipment which gives the required shape to automotive body components and forms an important function in the automobile manufacturing process. Subsequently, under expansion program, another Press was proposed to be installed in the existing facility. The existing facility with one Press (Press no. 1) has numerous activities going on with variable heavy weight dyes, storages and conveyance equipments all around it which serve as paraphernalia. (See Fig. 1).

The challenge was placed before Mahindra Civil Engineers to install another Press (New Press) in limited space of 16m x 16m available for Press foundation raft of size 11.5m x 11.5m to be placed at about 12.50m depth below existing floor level. The challenge was twofold, firstly to excavate safely to required depth (about 10m deep in filled up ground and another 2.5m in virgin ground.) and secondly, without interrupting manufacturing process with overhead crane in operation in the area. The area is continuously subjected to vibration from adjacent press. Dies were also stored around area to be excavated. Above all, work had to be completed in stipulated time period of 60 days.

Fig. 1 : Dies Stored Close to Proposed (New) Press Area

1.2 Soil Condition

The area where the new Press foundation was proposed to be installed was made up ground with murum and boulders. Only top about 1.5m was compacted. But, it was not known before as to what extent compaction is done. A loose material with boulders has tendency to slide more easily and very prone to caving. (See Fig. 2)

Fig, 2 : Soil Condition

Grain size analysis for a soil sample (depth 0.6 m) worked out and presented in the table 1 and Fig. 3 below :

Table 1 : Grain Size Analysis

Fraction	Content
Gravel (coarse & fine)	81.00 %
Sand (coarse, medium & fine)	17.00 %
Silt & Clay	02.00 %

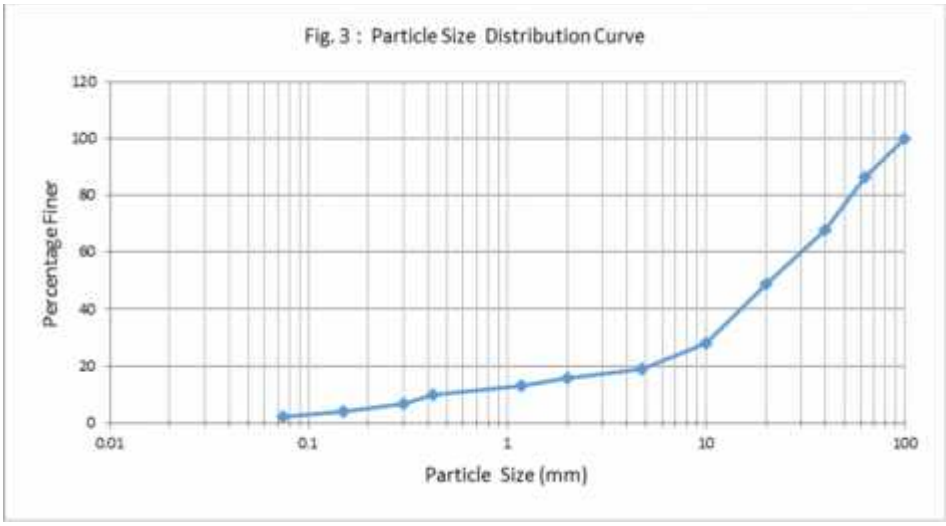


Fig.3 Grain Size Distribution Curve

Groutability ratio (penetrability of cement in in-situ soil) = 29.91 > 25

2. Soil Support Methods

2.1 Excavation without Support

This method consist of excavating pit with sloping sides which the material can stand with and without berm at intermediate level. With side slope of 1V:1.5H, the top size works out to be 47.5m x 47.5m at floor level. This option was ruled out due to space constrain and possibility of caving in of side slopes. (Available space 16m x 16m at floor level)

2.2 Excavation by Retaining Soil by Piles

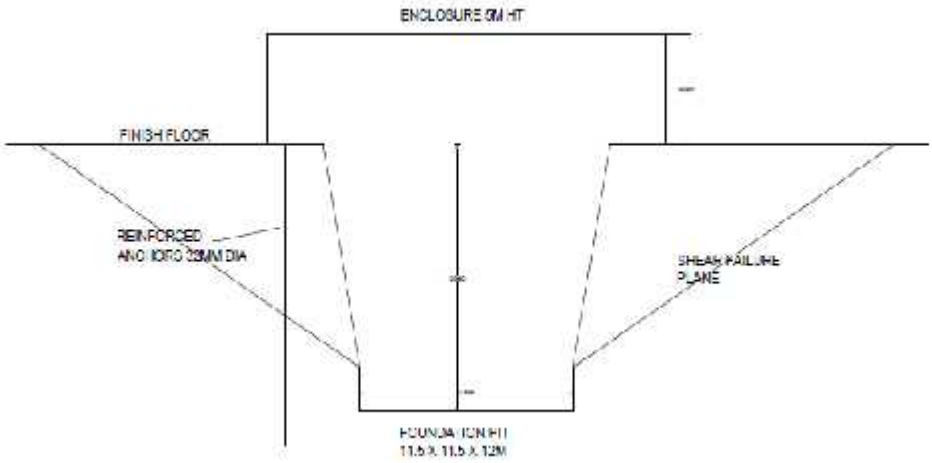
In this option, first choice was to drive steel piles. Since, soil strata consisted of murum with boulders, driving was not feasible. Therefore, the other option available was to go for bored cast in situ concrete piles. It was decided to provide 600 mm diameter concrete piles in a row along three sides. The fourth side left for access for excavator and for removal of excavated material. Considering 3m wide working space around 11.5m square area, the plan size required is 21m x 21m.

This option again was not attractive due to non-availability of working space for drilling, time required for drilling and casting piles and more cost involved.

2.3 Stabilizing Soil Strata by Grouting

Initially it was thought to stabilize strata by injection grouting of cement slurry via drilled holes by inserting perforated pipes. Three parallel rows of drill hole were planned. Then excavate progressively. Additionally, excavated surface could be protected by applying mortar.

The grout will flow in to void spaces to bind loose particles together, so that grouted portion will act as composite wall which will retain back material.
The area above shear failure plane is unstable. Factor of safety worked out for soil mass will be 0.54 which is unsafe. It's practically not possible to go for any type of open excavation. The unstable soil mass needs to be strengthened and self-supporting too.
In this unstable soil mass inter connecting particle bonding was increased by grouting cement slurry in different proportion. The said soil mass was reinforced by providing 32mm diameter steel reinforcement bars. Thus addressed instability of soil mass above shear failure plane. Which was retained excavation side nearly in vertical position.
This option looked attractive for following reasons. One is that it could be done in limited available space, secondly possibility of completing work in stipulated time and cost effectiveness.



Fig, 3 : Line Diagram for Methodology Adopted

3. Methodology Adopted

To start with the area got cleaned by shifting stored dies. The dies were stored along periphery of area to be excavated due to non-availability of other suitable space for storage. Area was enclosed by providing cladding along three sides and green cloth at top to control the dust. For the movement of machinery west side access was provided. West side access was made possible by dismantling existing wall resting on ground beam. Ground beam was also had to be removed by cutting it from columns. At lintel level structural steel beam was introduced for that bay in order to compensate the removal of ground beam.
Drilling of 100 mm hole started using wagon drill machine. Drilling could be done without much difficulty up to about 1.50 m depth. Further drilling process got struck due to rotation of loose particles at the bottom of cutting edge and side collapses. Since further drilling was not possible, it was decided to inject cement grout from this drilled hole. Accordingly cement slurry in 1:2 proportion injected under atmospheric pressure. Next day further drilling tried in the already drilled hole. It was possible to drill further about 1.50 m depth below. This proved that grout helped to bind loose particles together which facilitated further drilling. (See Fig. 3)

Based on this experience, it was decided to drill holes along periphery at 2 m spacing in a staggered manner in two rows. Accordingly, drilling of two row of holes completed up to about 1.5 m depth. Then cement slurry injected through all holes. About 1000 liters slurry was used per hole up to 6 m depth and 500 liters slurry for further depth. This drilling in stages of about 1.5 m and then grouting continued to reach a depth of 10 m. A 32 mm steel rod inserted in each hole and then hole grouted with cement sand mortar in 1:1proportion. Total number of holes along three sides were 60.

After a gap of 7 days excavation from central size of 11.5 m x 11.5 m started. Initially excavation up to 6 m depth done. During vertical excavation side collapses took place. After reaching to 6 m depth, side unstable material removed to get natural slope. In order to stabilize and strengthen this slope further, cement slurry applied along slope and then cement sand mortar in proportion 1:1 applied manually on surface along the slope.

Further excavation then started and reached to 10 m depth where natural ground surface met. After 6 m depth, it was observed that the fill material content was mainly boulders with little murum. The risk of rolling down of boulders here was very much felt. Few boulders came down while excavating lower portion. At North-West corner, a big chunk of fill material collapsed reaching up to grouted line on North side. This collapse also exposed the RCC column pedestal. It was observed that, where filling was done in compacted layers, a horizontal cement slurry layer formed, which improved the inter-layer bonding.

Natural virgin ground met at about 10 m depth. Further excavation was very much required in order to reach to rock strata. The weight of Press along foundation is more than 2000 tons. Such heavy machine foundation had to rest on strong and stable strata. Further 2 m excavated to reach to rock strata. This 2m depth excavation was very risky due to presence of boulders above in fill layer along three sides. Labors refused to work at that level. Therefore, as an addition measure to safeguard labor and create confidence in their mind, steel mesh was laid all along the slope. Considering risk of boulder collapse, it was decided to excavate partly and immediately fill the excavated portion with plum concrete so that toe of slope of fill material will not remain unsupported for long period. Accordingly, part excavation done and filled with plum concrete. Then remaining portion excavated and filled with plum concrete to complete the square portion. After excavation immediate concreting done, concrete was kept ready while excavation going on. Day-night work continued till got completed. This worked to our satisfaction without any side collapse.

Further concreting of raft foundation was done by creating a toe support along all four sides. Proper concreting of raft done after placing reinforcement in square space formed by concrete toe wall.

Fig.4 : Mortar Application on Slope

Fig.5: Plum Concrete Laid in Part Area

3.1 Cost Comparison

Approximate cost worked out for each method and presented in table 2 below

Table 2 : Cost Comparison

Method	Cost Rs.
Open Excavation	101.27 lakh
Retaining by Piles	153.14 lakh
Injection Grouting Method	25.57 lakh

4. Conclusion

In this work, different solutions were thought as and when difficult situation met with. The work completed within stipulated time without any accident of whatsoever nature and magnitude. The methodology adopted worked out to be cheapest of the available methods for deep excavation. The Press is presently in working condition.

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