Technical Report

Soil improvement Design of Turkish embassy Baghdad-Iraq

(Under Foundation System)

Client:

Turkish embassy

EPC Contractor:

Ardh Alnahrain co

Soil improvemen work and foundations

RP-TE-001-R00(PR-AB-0001)

بسم الله الرحمن الرحيم

GOD

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INTRODUCTION:

According to request of the client for foundation soil improvement design, this document presents the information and technical specifications for subgrade improvement of Turkish embassy building project.

This document consists of 2 main parts as follows:

1- An introduction to this project

2- Analysis and design of soil improvement system

1) PROJECT SPECIFICATION

1-1) *GENERAL CONDITION*

The proposed site is located in Governorate of Baghdad,. Figure 1-1 indicates location of damaged building in embassy site. According to client data This building suffer for excessive foundation displacement.

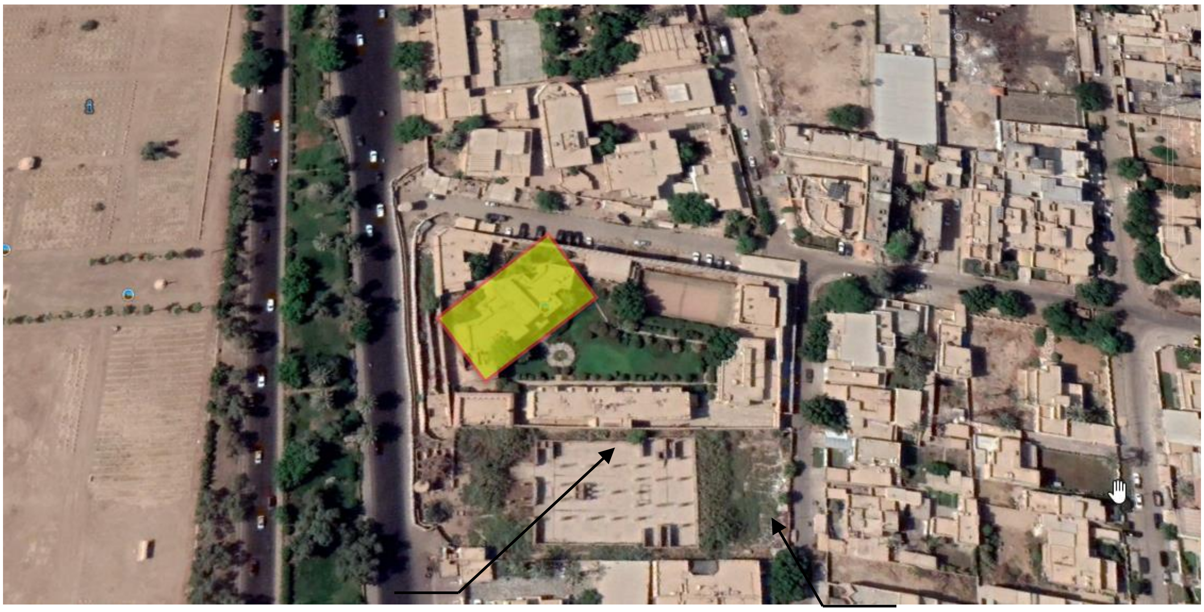


Fig. 1-1 location of damaged building in embassy site

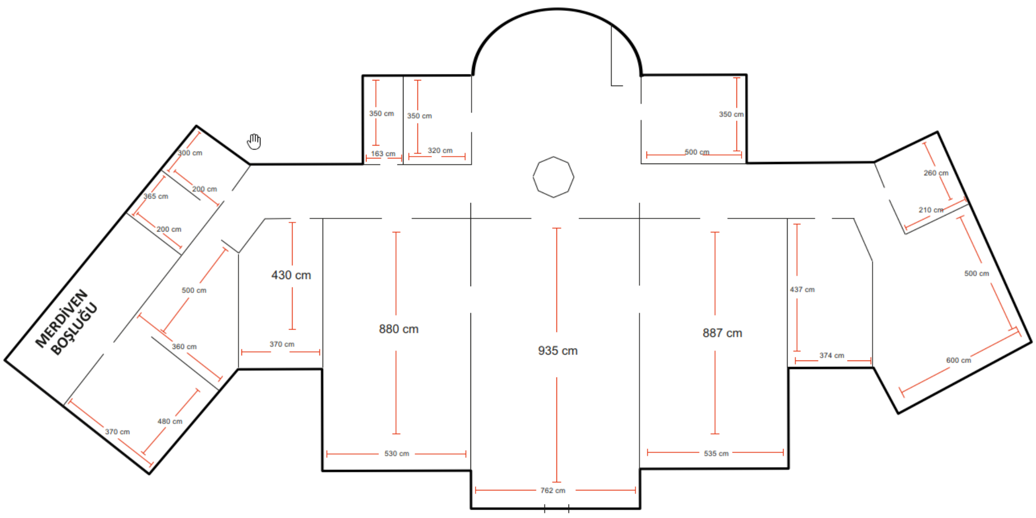


Fig. 1-2 plan view of ground level of damaged building

Based on received data in building body create some cracks And it seems that these cracks are still expanding in the entire body of the building despite successive repairs. Following figures indicate cracks in the body of this building.

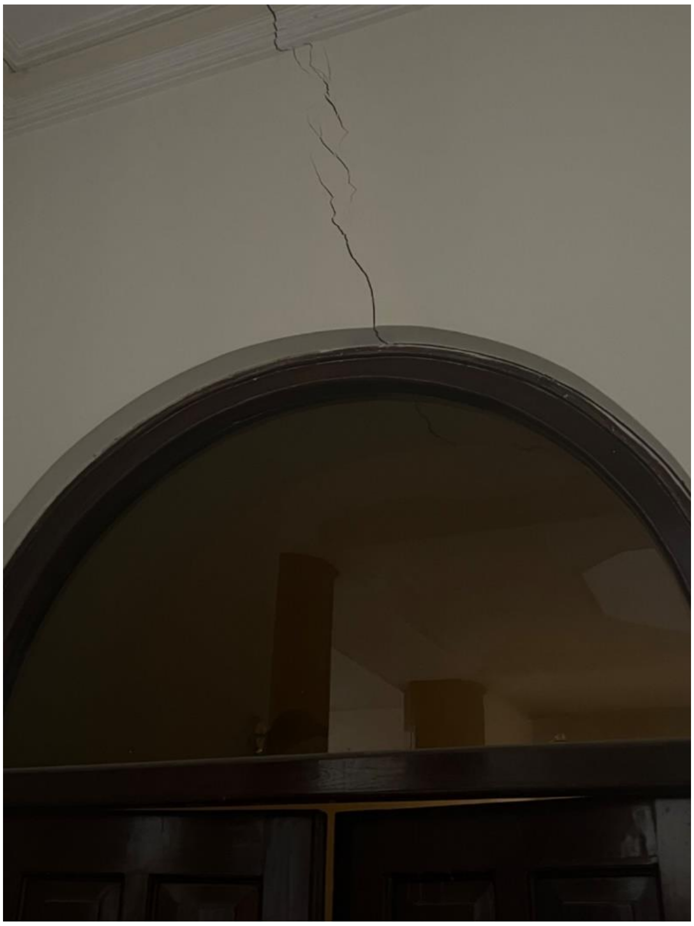


Fig. 1-3 crack in building body due to foundation displacement

Fig. 1-4 crack in building body due to foundation displacement

Fig. 1-5 crack in building body due to foundation displacement

1-2) *GEOTECHNICAL CONDITION*

According to the soil investigation report by alshams laboraqtory (Jan 2024), Soil profile are consisting as follows:

- The first soil layer is cohesive soil was appeared in boreholes BH.1 & B.H.2, which consists of medium stiff to very stiff brown fat silty CLAY with more broken bricks, some of organic materials and rusty areas. This layer extends from the natural ground surface (N.G.S) down to (7.5 – 12.0) m. depths.

- The second soil layer is cohesion-less soil, which consists of medium dense grading to dense grey silty sand or sand with clayey lenses. This layer extends from (7.5 – 12.0) m down to the end of boring at (20-25) m. depths in two boreholes. the subsoil profileis shown in following figure.

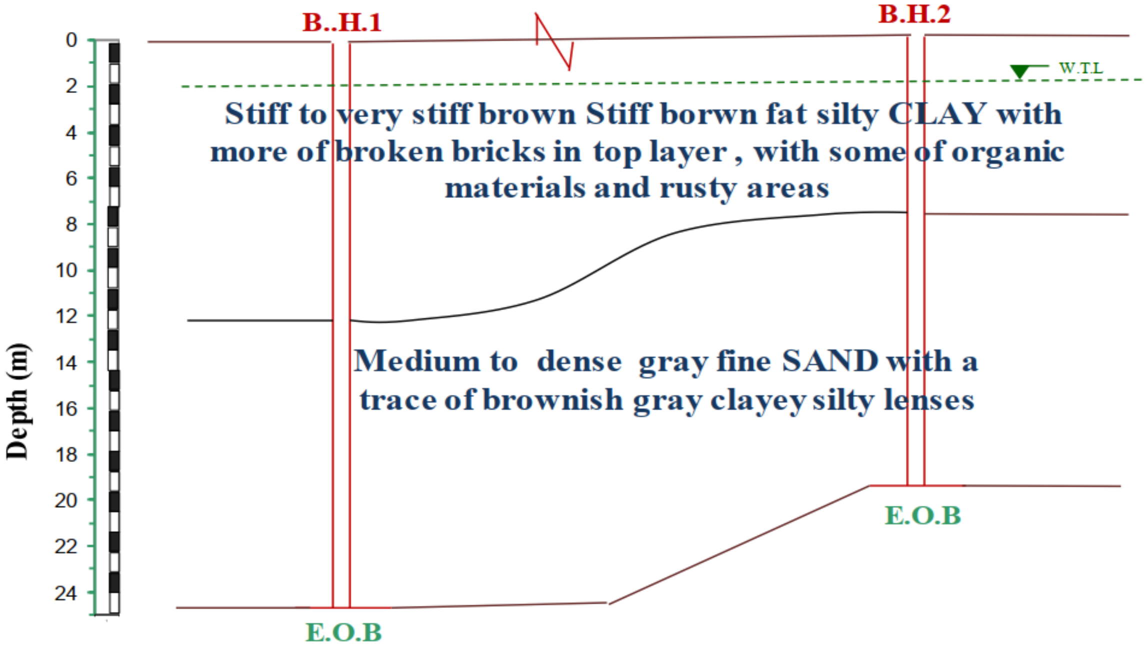


Fig. 1-6 Soil profile

Based on soil report data subgrade addition to having the settling potential, has the potential of swelling.

This potential in soil layer is not constant and vary based layer depth. This issue can cause heave the building and subsequently it can lead to create cracks

Soil formation and the selected characteristics based on soil investigation are as mentioned in table 1-1.

Table. 1-1 Soil characteristics parameters

Depth (m)	C (kg/cm2)	Φ°	E (kN/m2)	OCR
0-12	10	22	6000	2.1
12<	10	35	29000	1

It is noticeable that the soil strength parameters are derived from averaging between strength parameters in different strata. Soil elastic modules (E) are also derived from averaging between resulted E values from different relations between SPT values and soil elastic modules available in technical literature.

Based on soil report and cracks patterns, it seems both phenomena including settlement and heave can lead to create these cracks in building. Accurate detection of heave or settlement should be done using monitoring instrumentation. But the installation and reading of these instruments requires spending a considerable time, which will cause more deformation in the building, and this settlement can lead to permanent damage to the structure. Therefore, in the next section, design should be done in such a way that in both case of settlement or heave, the retrofit elements can prevent the increase of cracks.

2) *ANALYSIS AND DESIGN*

Based on project condition in order to stabilize subgrade, micropile has been used. Using micropile is one of the conventional methods for retrofitting structures. The reason for this issue is due to the ability to implement this method inside closed spaces. In this respect, in next section, micropile will be designed based on superstructure load. According to estimation, 250 kPa has been adopted for walls pressure on top of soil below foundation level. Also, embedment depth of foundation is considered -1.5 m

Design and analysis

In order to design micropile system “FHWA-NHI-05-039” has been used. based on structure condition, settlement is most critical issues. In this respect in order to design micropile system, in first stage, settlement of foundation without any soil improvement elements has been investigated in PLAXIS 3D 2023 FEM software. in this model all of soil characteristics have been adopted according to previous sections and all of stages in construction of foundation have been captured in staged construction analysis. It should be noted that due to existence of strip footing, only 4.5 m of this footing has been modeled. Results of analysis are depicted as follows.

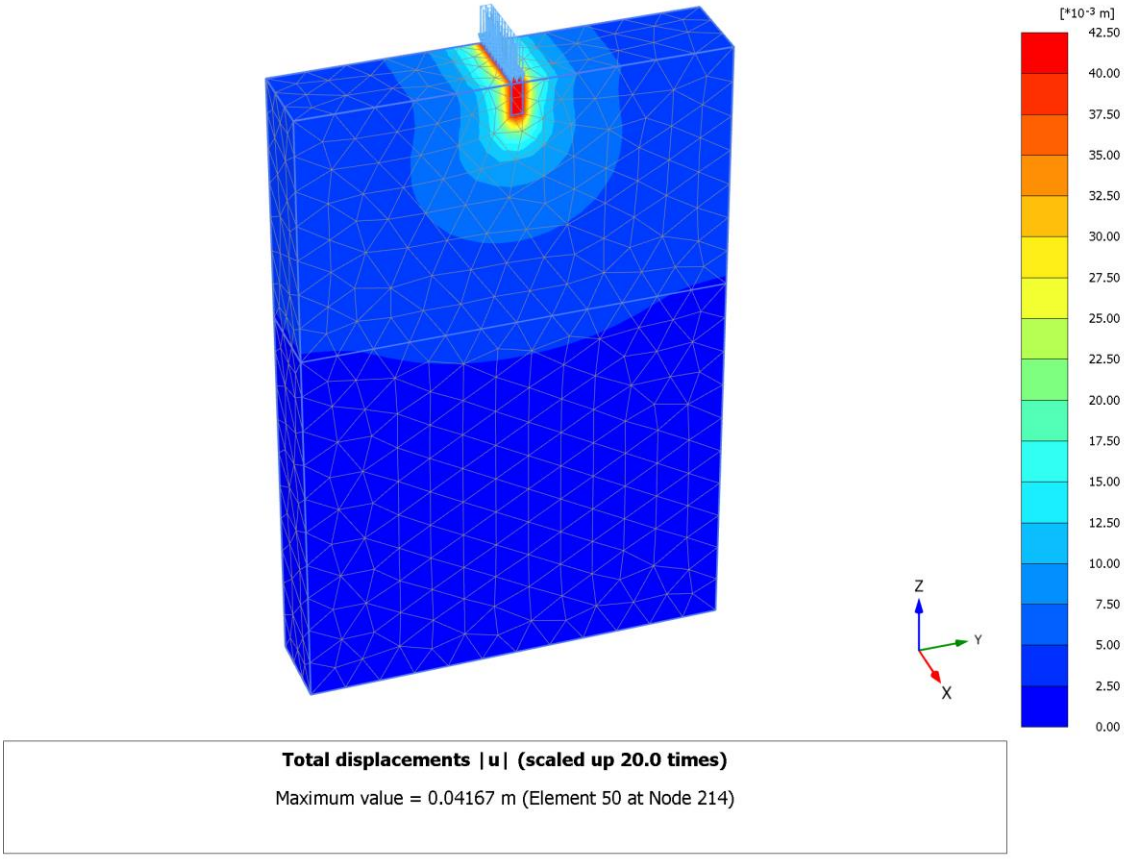


Fig. 2-1 settlement below foundation

According to above figure settlement below foundation are not in tolerable amount. In this respect soil improvement system using micropile should be designed.

micropile design

In order to perform numerical calculations, PLAXIS finite element software for geotechnical works has been used, and layering has been considered according to the geotechnical studies received from the esteemed employer.

To model the soil, the Hardening Soil behavioral model was used, whose parameter values were presented in the previous chapter. It should be noted that for the modeling of the soil micropile elements, beam elements has been used.

In order to better investigate soil behavior and to consider the effect of the interaction of the structures with each other, a three-dimensional model has been developed. Figure 2-3 shows a view of the built models. In these models, micropile elements has diameter of 10 cm and young modulus of 20 GPa. Also, masonry Wall thickness is 50 cm.

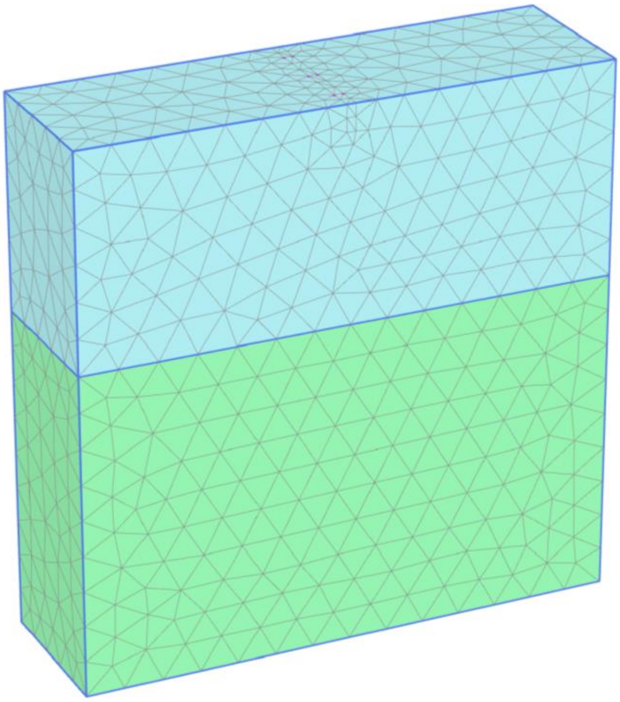


Fig. 2-2 3D Mesh generation of model

The arrangements for the micropile spacing are 1.5 meters and the micropile length is 12 m.

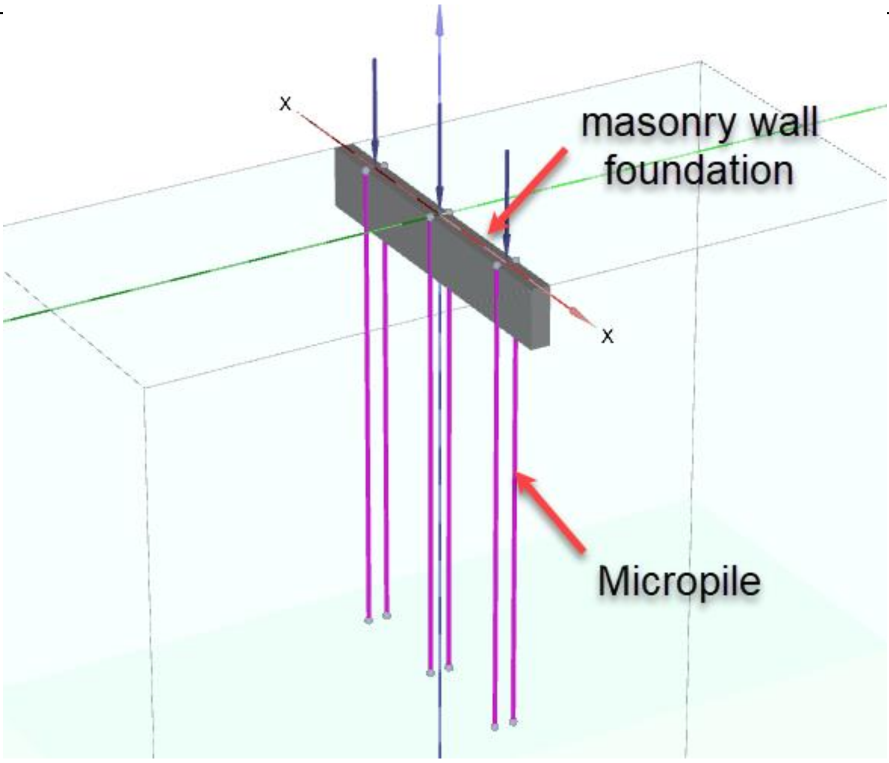
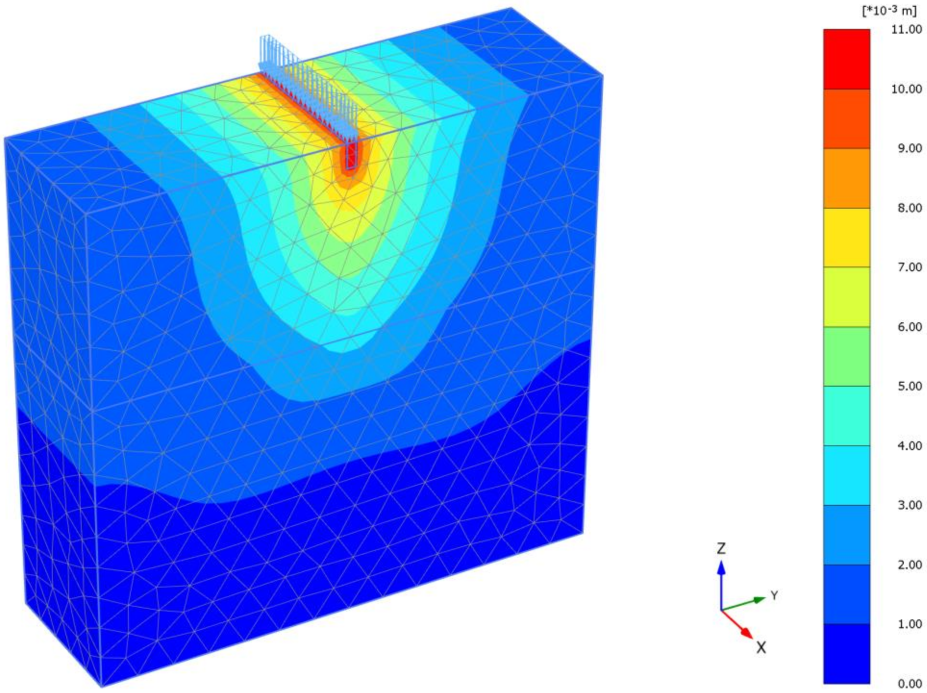


Fig. 2-3 micropile elements in model

Following figure shows the modeling outputs for the conditions after the improvement. As can be seen, the amount of settlement created after the soil improvement has reached to the tolerable limits (1 inch) for project structures based on well-known references.



Total displacements |u| (scaled up 100 times)

Maximum value = 0.01040 m (Element 80 at Node 12)

Fig. 2-4 settlement below foundation level after micropile installation

Considering the load of the structure, in order to calculate the micropile structure, the capacity created by the soil will be ignored and it will be assumed that the micropiles will bear the load lonely. Based on this assumption, the load reached to each micropile is equal to 9.5 tons.

In order to design element under swelling pressure, based on soil report maximum swelling pressure are lower than 50kPa. If this pressure inserted to tributary area of each micropile, maximum tensile load of each micropile is 2 ton. In this respect micropiles should sustain both load with opposite direction in our calculations. In this regard, the design of these elements will be discussed further.

Micropile Structural Design

$P_{c\text{-}allowable} = 0.4\, F'c_{grout}\, A_{grout} + 0.47\, (F_{y\text{-}bar}\, A_{bar})$

Use Bar 32 AIII

$F_{y\text{-}bar}$ = 4000 (kg/cm^2)

$f'c_{grout}$ = 150 (kg/cm^2)

$Area_{grout}$= 42.20 (cm^2)

$Area_{bar}$= p$(OD^2\text{-}ID^2)/4$= 8.04 (cm^2)

$P_{t\text{-}allowable} = 0.55\, (F_{y\text{-}bar}\, A_{bar})$

$P_{t\text{-}allowable}$ = 17.69 (ton)

$P_{c\text{-}allowable}$ = 17.7 (ton)

Micropile Geotechnical Design

$P_{G\text{-}allowable}$ = ($a_{\text{bond nominal strength}}$) * 3.14 * (DIAbond) * (Bond Length) / F.S.

Soil description : clay - Silt

$a_{\text{bond nominal strength}}$ = 50 (kN/m^2)

Factor of Safety (F.S.) = 1

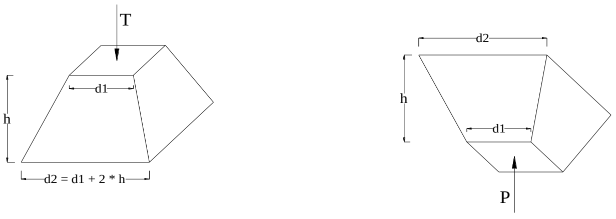
DIA_{bond} = 0.08 (m)

Bond length = 12 (m)

$P_{G\text{-}allowable}$ = 15.4 (ton)

5-3- Check for Cone Shear

According to ACI349 Appendix "B"



Required Plate Area

Assume a square plate with width = 150 (mm)

Area plate = 22500 (mm^2)

Equivalent diameter for circular plate = d_1 =

169 (mm)

$F'c_{foundation}$ = 100 (kg/cm^2)

h = 200 (mm)

d2= d1+2*h = 569 (mm)

232011 (mm^2)

Check Cone Shear
Use ACI 349 Appendix B for cone shear

$$P_{cone\ design\ strength} = 4\varphi\sqrt{f'_c(psi)} \times A_{CP}$$

$$= 4\varphi\sqrt{f'_c(psi)(6.89\ 476)\frac{(kPa)}{(psi)}} \times A_{CP}$$

$$= 10.5\,\varphi\sqrt{f'_c(kPa)} \times A_{CP}$$

$$P_{cone\ nominal\ strength} = 10.5\sqrt{f'_c(kPa)} \times A_{CP}$$

= 1680 (kN)

$$P_{cone\ allowable} = \frac{P_{cone\ nominal}}{FS}$$

FS = 2

$P_{cone\ allowable}$ =	85.6	(ton)

2-1) Wall and micropile Connection

In order to connect micopiles to structure first of all two parallel beams should be implemented at two side of wall. These beams are located on top of micropiles. In order to connect these beams to walls, walls should be drilled at each 1.5 m with the width of 30 cm. at these holes, reinforced concrete beam should be implemented So that the beams are connected to each other on both sides of the wall, and in case the wall settles or heaves, these beams do not allow the wall to displace by relying on the micropiles. This form of connection has the advantage of not allowing the wall to heave if the load is facing upwards.

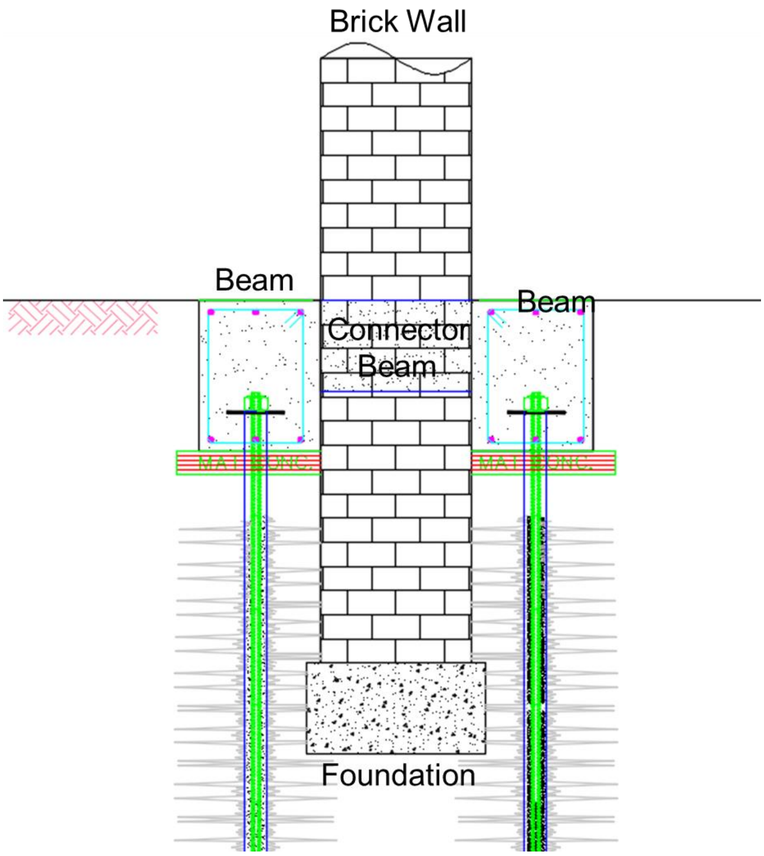


Fig. 2-5 section view of connection between structure and masonry wall

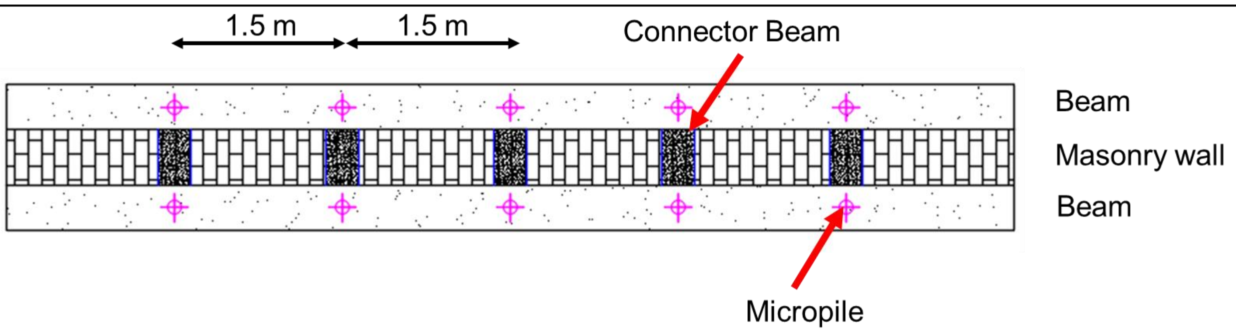


Fig. 2-6 plan view of connection between structure and masonry wall

2-2) Work volume:

Based on previous calculations plan arrangement of micropiles has been shown in following figure. According to this drawing 218 micopiles with length of 12 m should be implemented at the site.

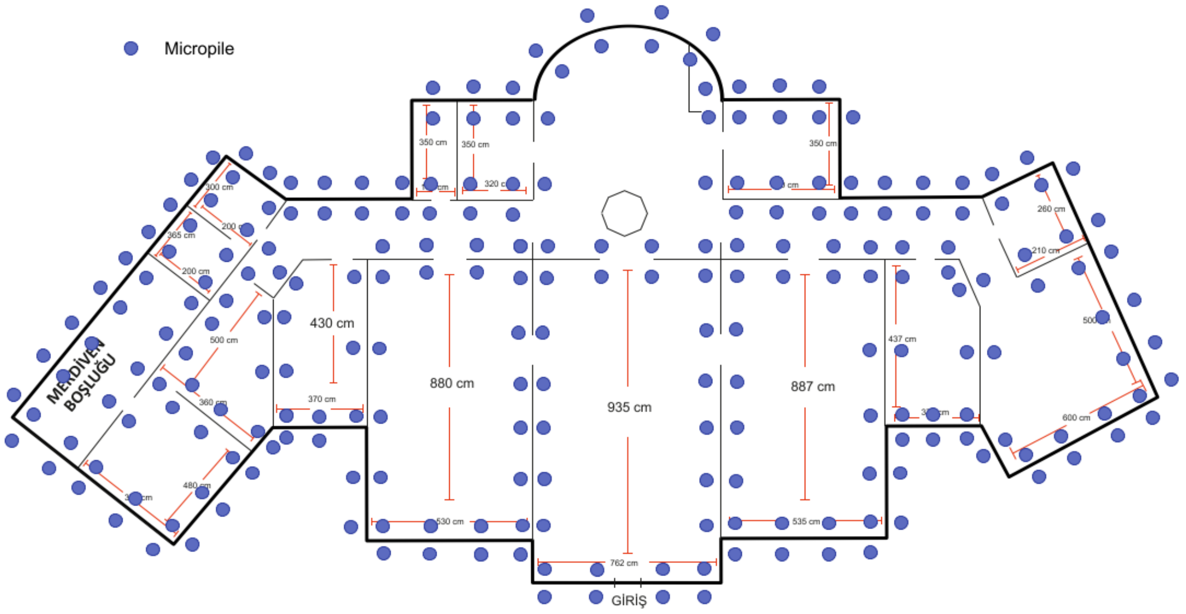


Fig. 2-7 plan view of micropile arrangement

Based on drawing, work volumes of project are approximately as follows.

	Description	unit	amount
1	Micropile with 12 m length	meter	2868
2	Beam	meter	500
3	Connector beam	No	240