# Case Study on Underpinning of Foundation for an Industrial Building Renovation

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**Abstract.** Underpinning involves strengthening of foundation for existing structures using various methods. One of the suitable method is adapted according to the subsoil and site conditions. One such method is extending the dimensions of existing foundation to rest under supportive soil strata. This method is effective in renovation of existing buildings where more space is available for working condition and requires skilled manpower. This paper deals with a case study on underpinning for an Industrial building at Virudhunagar, Tamilnadu, India. Since there is a need for a conversion of an existing spinning mill to an Industrial plant, the necessity for strengthening the existing structures was proposed. The suggested method of Underpinning by extending the breadth and depth of existing foundation was carried out and the outcome proved to be successful. Underpinning involves strengthening of the foundation for existing structures using various methods. One of the suitable methods is adapted according to the subsoil and site conditions. One such method is extending dimensions of the existing foundation to rest under supportive soil strata. This method is effective in the renovation of existing buildings where more space is available for working condition and requires skilled manpower. This paper deals with a case study on underpinning for an Industrial building at Virudhunagar, Tamilnadu, India. Since there is a need for a conversion of an existing spinning mill to an Industrial plant, the necessity for strengthening the existing structures was proposed. The suggested method of Underpinning by Increasing the breadth and depth of the existing foundation was carried out and the outcome proved to be successful.

**Keywords:** Existing Building; Foundation; Underpinning ; Industrial building; Renovation; Case study

## 1 Introduction

Underpinning is a process of strengthening the existing foundation of a structure. This may be required in case of ground subsidence, excessive settlement of the structure, construction of a new basement beneath a building, change in the usage of structure, increasing the height of the existing structure and enable a building to be with stand the additional loads [1]

A team of researchers in Nigeria [2] investigated the cause and the suitable remedial measures for the foundation failure. It has been found that differential settlement was the major reason and providing new continuous strip foundation was the widely accepted remedial measure.

A potash refinery industry near Regina, Saskatchewan has investigated [3] to double the production capacity. The existing sub structure has pile foundation with pile cap. After the careful study of sub soil and analyzing for the additional capacity additional pile with extended pile cap suggested.

In this case study, an existing spinning mill industry of height 6 m at eaves level and 9m at ridge level is proposed to be modified to suit for the polymer film manufacturing industry. The span of the existing and proposed truss was maintained same as 15m. The new polymer film industry has a requirement of 22m clear height at eaves level and 25m at ridge level to enable new machinery to be installed for the production. The typical cross section of existing and proposed modification of structure shown below (see Fig. 1).

The factory authorities entrusted M/s. Karthikeyan associates, Chennai, India as consultants to renovate the Industrial building to fit for their best use. This operation would not only include renovation or remodeling but also requires rigorous rehabilitation from the foundation level. This paper deals with the entire underpinning of the existing foundation as well as structural rehabilitation.

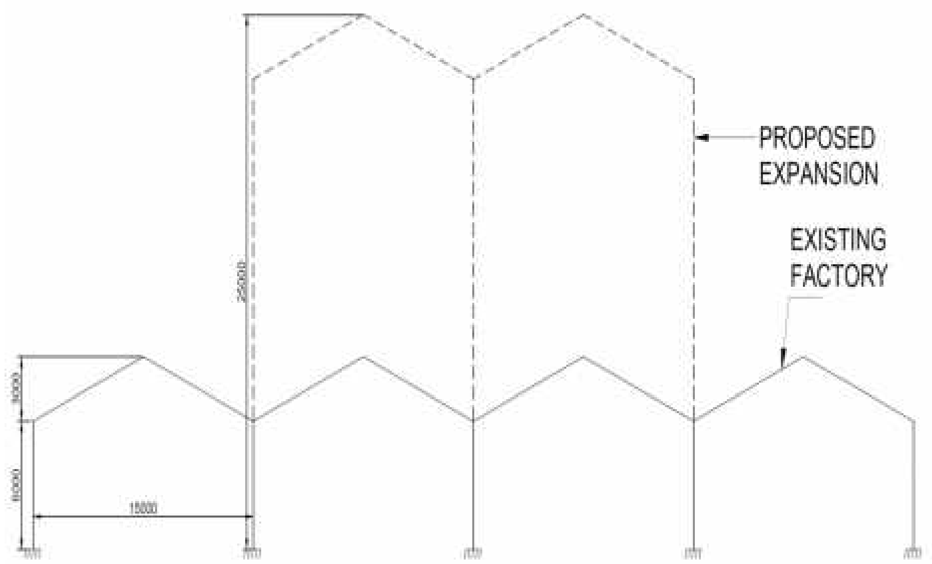


**Fig. 1.** Typical line diagram showing cross section of existing and proposed structure.

# 2 Existing Soil and Foundation

To analyse the existing foundation it is very important to study the characteristics of soil substrata. An field exploration was carried out upto a depth of 10.5 m from the existing level. To collect the undisturbed soil samples four numbers of bore hole done with in the site boundary. This soil exploration carried out by Sceba Consultancy Services, Madurai, Tamilnadu.

## 2.1 Sub Soil Data

Table. 1,2 and 3 gives the index properties of soil, geotechnical design and type of soil in critical borehole data out of four acquired from the soil investigation. The bearing capacity of soil [4] at 3.00m from finished floor level was calculated to be 157.5 kN/Sq.m. however considered as 150 kN/Sq.m. for design calculations.

**Table 1.** Index properties of soil sample from bore hole no.4

| Sl No. | Depth m | 'N' Value Corr. | Type of Soil | Density gm/cc | Liquid Limit % | Plastic Limit % | Plasticity Index % | Shrink-age Limit % | Degree Of Free Swelling % |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 to 1.80 m | 6 @ 1.5m | Type A | NA | 65 | 30 | 35 | 6 | 80 |
| 2 | 1.80 To 3.0 | 18 @ 3.0m | Type B | 1.75 | 39 | 18 | 21 | 12 | 50 |
| 3 | 3.0 to 4.50 m | 35 @ 4.50 m | Type C | >2.0 | Not Significant | Not Significant | Not Significant | Not Significant | 20 |
| 4 | 4.5 To 6.0 m | 45 @ 6.0m | Type D | >2.0 | Not Significant | Not Significant | Not Significant | Not Significant | 20 |
| 5 | 6.0 to 7.5m | Refusal @ 7.5m | Type E | >2.0 | Nil | Nil | Nil | Nil | Nil |
| 6 | 7.5 to 9.0m | Refusal @ 9.0m | Type F | >2.0 | Nil | Nil | Nil | Nil | Nil |
| 7 | 9.0 to 10.5 m | Refusal @ 10.5 | Type F | >2.0 | Nil | Nil | Nil | Nil | Nil |

**Table 2.** Soil geotechnical design of bore hole no.4

| Sl No | Depth m | 'N' Value Corr. | Type of Soil | Natural Density KN/M³ | Bearing capacity Parameter | | | 'Φ' Value in degree | C' KN/M² | SBC based on KN/M² | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Nc | Nr | Nq | | | "C" | Settlement for 40 mm |
| 1 | 0.0 to 1.80m | 6 @ 1.5m | Type A | NA | NA | NA | NA | NA | NA | NA | Highly Reactive |
| 2 | 1.80 To 3.0 | 18 @ 3.0m | Type B | 17.5 | 35.49 | 23.18 | 30.21 | 32° | NA | NA | **157.5** @ 3.0 m |
| 3 | 3.0 to 4.50m | 35 @ 4.50m | Type C | >20 | 55.63 | 42.92 | 66.19 | 37° | NA | NA | **336** @ 4.5 m |
| 4 | 4.5 To 6.0m | 45 @ 6.0m | Type D | >20 | 67.87 | 55.96 | 92.25 | 39° | NA | NA | **440** |
| 5 | 6.0 to 7.5m | Refusal @ 7.5m | Type E | >20 | 50.59 | 37.75 | 56.31 | 36° | NA | NA | **>450** |
| 6 | 7.5 to 9.0m | Refusal @ 9.0m | Type F | >20 | 75.31 | 64.20 | 109.4 | 40° | NA | NA | **>450** |
| 7 | 9.0 to 10.5m | Refusal @ 10.5m | Type F | >20 | 75.31 | 64.20 | 109.4 | 40° | NA | NA | **>450** |

**Table 3.** Detailed description of soil type for bore hole no.4

| Sl No. | Type | Description of Soil |
|---|---|---|
| 1 | Type A | (Made up soil sand with clay observed for 50 cm) Clay soil Black in color |
| 2 | Type B | Coarse to medium Lime Stones With Blackish Clay |
| 3 | Type C | Coarse Lime stone Gravel with cobbles and traces of weathered sand stone |
| 4 | Type D | Fragmented calcareous stone with sand stones and white fines |
| 5 | Type E | Combined Fragmented calcareous stones and sand stones |
| 6 | Type F | Hard strata |

### 2.2 Existing Foundation

The existing foundation was physically examined and measured which was an isolated footing with a circular column of dia 0.6m placed in the center. The size of the footing was 2.4m in both length and breadth with raft thickness of 0.45m.

## 3 Methodology

### 3.1 Analysis of proposed structure

We have analyzed the proposed structure in Staad pro software (See Fig 2.) and found that the existing foundation would not be sufficient to withstand the proposed extension and alteration of the structure. So, we have decided to strengthen the existing foundation, as well as the columns. The reaction from the structural analysis given for critical column shown below in table 4. The suitable underpinning method according to the site conditions adaptable was increasing the dimensions of the foundation to rest under supportive soil strata. In this, we excavated till the bottom of foundation with sufficient space to work and drill near to the existing reinforcement of the isolated footing and fixed new reinforcement grouted with an approved chemical. The rebar grouting is done along the foundation and existing column. The operation increases both the dimensions of the footing as well as the thickness of footing. The existing column was 600mm circular, but the structural requirement was 1400 X 1400mm square column using M20 grade concrete and Fe500 steel reinforcement. For this condition, the foundation structure also requires a higher thickness of 1000mm.

Below load combination as per IS 456:2000 [5] and IS 800:2007 [6] are considered

1. 1.5 D.L+1.5 L.L
2. 1.5 D.L+1.5 W.L
3. 1.0 D.L+1.0 L.L
4. 1.0 D.L+1.0 W.L
5. 0.9 D.L+1.5 W.L
6. 1.0 D.L+0.8 W.L
7. 1.2 D.L+1.2 L.L +1.2 W.L

Where
D.L = Dead Load
L.L. = Live load or Imposed Load
W.L= Wind Load

**Table 4.** Reactions (kN) from Builtup Steel Column to RCC column.

| Node No. | Fx | Fy | Fz |
|---|---|---|---|
| 4755 | 1.663 | 190.618 | 2.491 |
| | -29.806 | -437.552 | -2.807 |
| 4756 | 2.163 | 167.405 | 0.331 |
| | -0.195 | -359.807 | -0.104 |
| 4757 | 2.346 | 290.714 | 0.397 |
| | -0.201 | -147.346 | -0.183 |
| 4758 | 1.741 | 373.343 | 3.544 |
| | -22.954 | -188.378 | -6.369 |

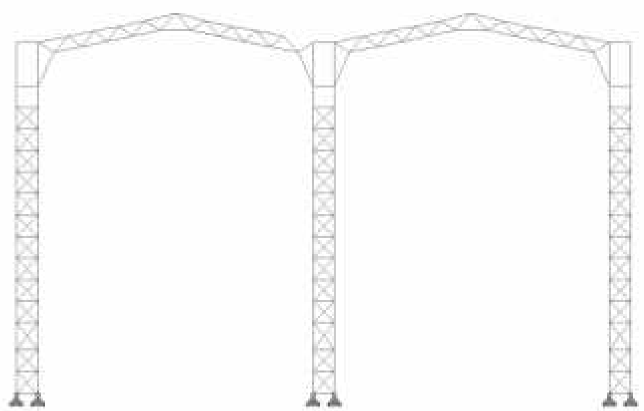

**Fig. 2.** Typical cross section  showing steel truss

The foundation was designed based on the following equation (1). Where *P* is working load on the column, *A* is the area of the foundation, *M* is the lateral moment, due to horizontal wind force and *Z* is section modulus of the foundation. SBC is Safe bearing capacity of soil.

$$\frac{P}{A} + \frac{M}{Z} \leq SBC \qquad (1)$$

### 3.2 Methods of underpinning

There are following methods of under pinning available

a. Underpinning by chemical injections
b. Underpinning by continuous strip foundations
c. Underpinning using micropiles
d. Underpinning using additional piles with extended pile cap
e. Underpinning by widening the size of foundation.

### 3.3 Decision making process

Some of the underpinning widely used shown above. In which chemical injections method can be used to increase the soil bearing capacity but it requires more construction time and evaluation of SBC requires further investigations. It may also be noted that the foundation is subjected to uplifting forces due to the wind action hence it requires larges base with mass concrete for good stability, hence it has been decided to widen the size of the existing footing from 2.4 x 2.4 m to 5.0 x 5.0 m.

### 3.4 Construction carried out

The existing steel roof truss dismantled over the proposed modification area, and it was kept safe for using again at elevated height with some strengthening. Then the excavation work carried out to a depth of 2.4m from the existing ground level and the size of the excavation maintained 5m x 5m at 2.4m level (See Fig. 3). One of the foundation after the excavation shown below in Fig. 4. After the excavation, the existing footing concrete cleaned and chipped off and bonding agent applied to create the good interaction between existing and new concrete. In addition to that, the reinforcement dowel 16mm dia rods grouted to the existing foundation at 150 mm c/c has shown in Fig.5 with the additional reinforcement before concreting and the same foundation shown in Fig.6 after concreting.

The proposed 1400 x 1400 mm RC column constructed over the renovated footing up to a height of 6M. Above the RCC column the steel column erected upto new eaves level at 22m heignt from the ground level. After the successful erction of all columns with the bracing, the roof truss erected over the steel column. The erected truss partially covered with the roof sheet shown in Fig. 7. After successful completion of this rehabilitation and renovation job, the structure was handed over to the mechanical engineering department to fabricate their machinery.

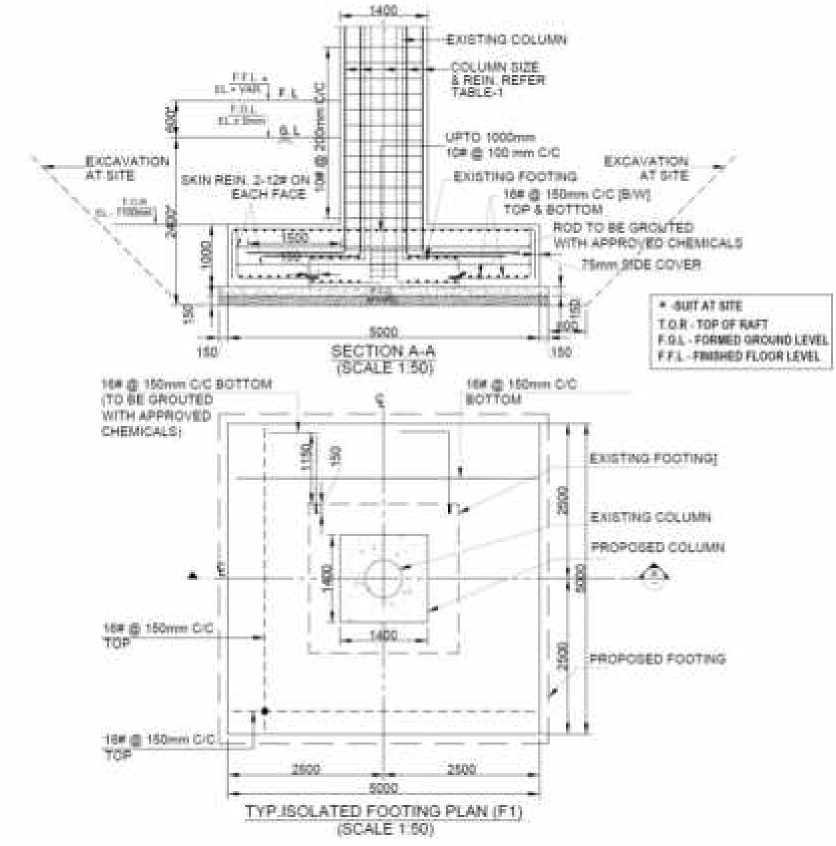


**Fig. 3.** Underpinning of Existing footing and Column details

**Fig. 4.** Site Photos showing existing footing and underpinning before concreting

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**Fig. 5.** Site Photos showing underpinning before concreting

**Fig. 6.** Site photos showing footing after concreting

**Fig. 7.** Site photos showing the erected steel structure on renovated RC column over the Underpinned foundation

## 4 Conclusion

Underpinning is a state of art for Geotechnical and Structural Engineers with sound technical background. Structural engineers must have sound knowledge about the existing foundation and sub soil condition, plan for renovation and rehabilitation of the existing structure. Before rehabilitation process Non-Destructive testing (NDT) on existing structure is emphasized. After Underpinning periodical study of the renovated structure is also important.

In this renovated structure no specific monitoring device fixed for structural health monitoring due to cost constraints and cumbersome to fix and monitor regularly. The industrial structure has been serving for more than 4 years experienced all climatic conditions without any sign of distress being observed during our periodic site visit. This project get success not only because of structural strengthening but also due to strong underpinning.

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