

Performance Based Analysis of Gable End wall Foundation

Project: -----
Report date: November 04, 2022
Customer: Mr. Mathew
Prepared by: Sikandar Ali, Touqeer Ahmed, Zain ul Hassan

Table of Contents

S. No	Contents	Page no
1.	INSTRUCTIONS.....	3
2.	SCOPE OF THE REPORT.....	3
3.	INTRODUCTION.....	3-4
4.	PROJECT DETAILS AND BACKGROUND.....	4-6
5.	STRUCTURAL ANALYSIS	6-9
6.	CONCLUSIONS.....	9
8.	RECOMMENDATIONS.....	10

1. Instructions

- I confirm your instruction to carry out a detailed structural analysis and viability of proposed fiber reinforced concrete (FRC) wall footing supporting the gable end concrete blocks wall of **“63, Heol Cae Gurwen, Gwaun Cae Gurwen, Ammanford, Neath Port Talbot SA18 1HG”** project.
- To produce a written report based on findings from the analysis and provide recommendations.
- This report is based on a Linear and Non-linear Finite Element analysis examination of the wall footing. The analysis is based on idealized constitutive modelling based on material specifications provided by the client.
- Foundation is analyzed with averaged value of bearing capacity of underneath soil due to unavailability of geotechnical report.
- The Final comments and recommendations on the capacity of foundation are evaluated using performance-based analysis which will not necessarily be as per British standard codes.

2. Scope the report

This report is produced as result of Non-linear Finite element analysis of wall footing under clayey soil supporting the gable end with load of two simply supported steel beams running all the way from one end to other. Our report is limited to the scope of this task. We have not inspected parts or problems which are not relevant to this request.

3. Introduction

The footing is a structural member that safely transmits the load of the upper building to the ground and is the first to be constructed member of the building. To efficiently transfer the loads, different types of foundation are recommended depending on the overlaying structural members and their stresses. The basic method of footing design is to distribute the load so that the size per area of the load transmitted from the upper part of the building is less than the strength that the ground can support, that is, the bearing capacity.

The design and the construction of a well-performing foundation must possess some basic requirements that must not be ignored. They are:

1. The design and the construction of the foundation is done such that it can sustain as well as transmit the dead and the imposed loads to the soil. This transfer must be carried out without any significant settlement that can result in any form of stability issues for the structure.

2. Differential settlements should be avoided by having a rigid base for the foundation. These issues are more pronounced in areas where the superimposed loads are not uniform in nature.
3. Based on the soil and area it is recommended to have a deeper foundation so that it can guard any form of damage or distress. These are mainly caused due to the problem of shrinkage and swelling because of temperature changes.
4. The location of the foundation chosen must be an area that is not affected or influenced by future works or factors.

In a general, the footing design is to determine the area of the footing, the thickness of the footing and the amount of required rebar that will exceed the demand of applied load.

4. Project details and background

The building “**63, Heol Cae Gurwen, Gwaun Cae Gurwen, Ammanford, Neath Port Talbot SA18 1HG**” is being redeveloped due to failure of party wall subjected to differential settlement. The party wall was subject to load transferring from overlaying beam. which was difficult for the soil under the wall with small step footing area of foundation to bear the load. Figure 1 show the failure of the party wall.



Figure 1. Differential settlement of the party wall

So, the new proposed plane is to remove the load from party wall and transfer it to newly constructed gable end Wall using 6” 10n blocks laid flat to form a 9” wall. The load is being transfer through two 9.5 m long simply supported steel beam having maximum bending moments of 111.86 KN-m. Figure 2 show the proposed plane of gable wall. Figure 3 show the locations of steel beams transferring the load to gable wall.

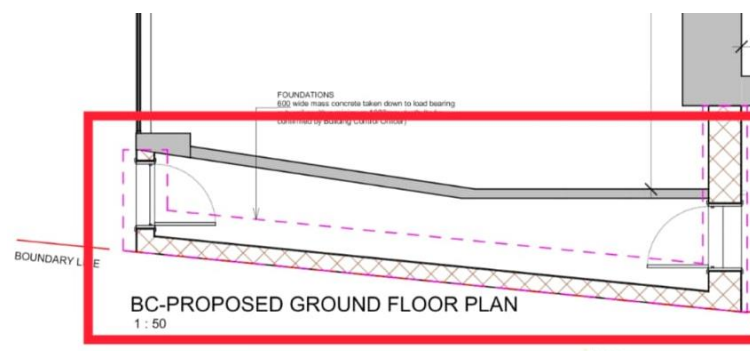


Figure 2. Proposed plane of gable wall and underneath footing

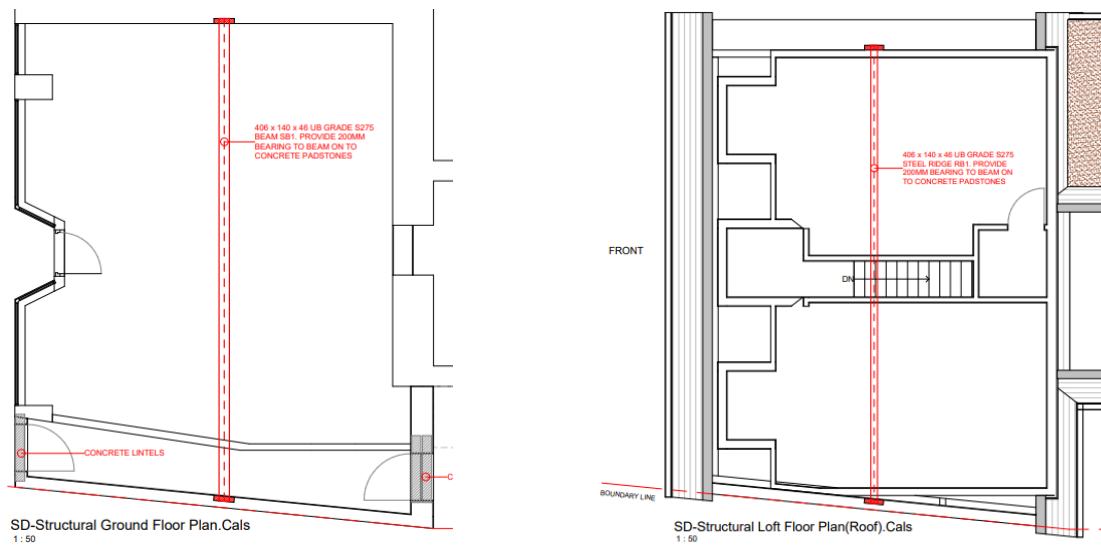


Figure 3. locations of steel beams transferring the load to gable wall

To prevent the gable wall from producing identical outcomes of differential settlement, the footing is needed to be design with more care. The proposed footing for this project is 7.5m long, 0.735-1.02m wide, and 1 m deep wall footing under gable end with concrete C40 Structural (RC32/40 Material code 39250, cement CIIIA) and Fibrin XT fibers at the dosage of 0.9 kg/m³. Figure 5 show the dimensions of proposed footing.

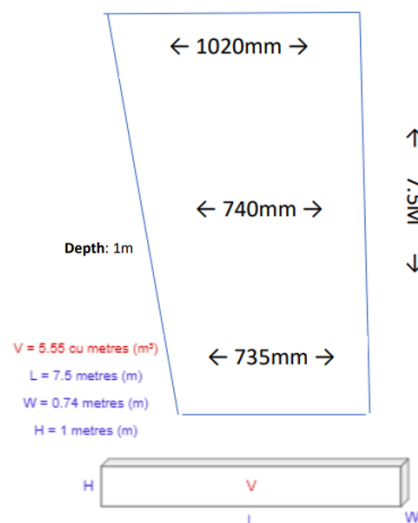


Figure 4. Dimensions of proposed foundation

So, the objective is to evaluate the proposed foundation's performance and safety under the specified loading conditions.

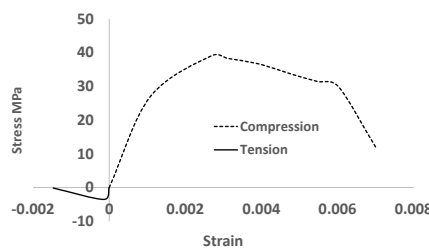
5. Structural analysis

Analysis is conducted using linear and non-linear Finite Element Analysis. The material properties, loading from steel beams, and boundary conditions are discussed below:

5.1. Material properties:

The proposed footing for this project is 7.5m long, 0.735-1.02m wide, and 1 m deep wall footing with concrete C40 Structural and Fibrin XT fibers. Table 1. Show the Calculated and assumed properties of Concrete used in foundation. Table 2. Show the properties of Fibers used.

Table 1. Properties of C40 concrete.

Concrete	Specifics	Elastic Modulus	Poisson's ratio	Stress-strain curve in Compression & Tension
C 40	RC32/40 Material code 39250, cement CIIIA	30 GPa	0.3	

Elastic modulus of C40 is calculated using BS 8110: Part II 1985 equation $E_c = k_o + 0.2f_{cu}$, Poisson's ratio is assumed to be 0.3, and stress- strain curve is obtained from Mander's model and tensile as per minimum modulus of rupture recommended by British standards.

In all kind of footings, there will always be flexural stresses in the cross-section. To resist flexural stresses, we needed some minimum tensile capacity to cater these stresses no matter what the size of cross-section we are using. If the tensile capacity is zero, which in real is not the case, the footing will always fail with any size of cross-section.

In Performance-based evaluation of proposed footing, incorporation of minimum modulus of rupture (as tensile capacity) in stress-strain was mandatory for taking tensile stresses generating due to flexural loads. The use minimum modulus of rupture can also be considered reasonable due to addition of Fibrin XT fibers that will show some sort of bridging action in concrete mix. Although, manufacture has clear declared that the use of Fibrin XT fiber will only be used to control creep and shrinkage issue and will not give additional stress. In short, footing will always give failure if we strictly compile to code but in performance-based design, that will more accurately mimic the actual behavior, can allow us to use the proposed size and material characteristics for given set of loadings.

Table 2. Properties of Fibrin XT fibers

Fibers	Type	Specifications	Dosage
Fibrin XT	polypropylene monofilament	22 μ m dia 13 -19 mm length	0.9 kg/ m ³

The shrinkage, creep, and thermal stresses in concrete are another reason why the code advises to use minimum amount of steel reinforcement. The problem is also disregarded with use of Fibrin XT fiber that will control the thermal, creep and shrinkages changes in concrete. Currently, the

sole concern is the passing of footing's capacity for a given load with no steel reinforcement. That will be checked using Linear and non-linear FEA analysis.

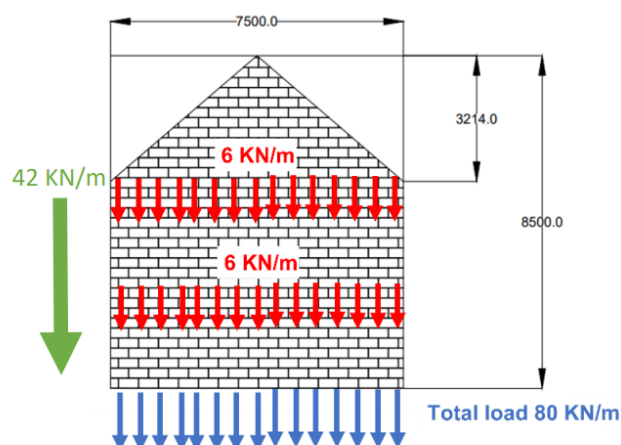
The detailed geotechnical report of the soil was not available; therefore, averaged values of stiff clay were incorporated for the analysis (as recommended by the client). Table 3. Summarizes the assumed parameters of soil for modeling.

Table 3. The parameters of soil

Bearing Capacity (KN/m ²)	Modulus of subgrade (KN/m ³)	Friction Angle	Cohesion (KN/m ²)
200	8000	0	200

5.2. Loading on the Footing:

The total load on the footing will be the load of wall constructed using 6" 10n blocks (unit weight of 22 KN/m³) and the load through two steel beams. The calculation of the total load is as following:



$$\text{Load of wall} = 0.225\text{m} \times 8.5\text{m} \times 22 \text{ KN/m}^3$$

$$= 42 \text{ KN/m}$$

$$\text{Load from steel beams} = 2 \times \left(\frac{112 \times 8}{9.5 \times 2 \times 7.5} \right)$$

$$= 12 \text{ kN/m}$$

: Maximum being moment=112Kn-m

$$\text{Total load on footing} = \text{FoS} (42+12) = 1.5(42+20) = 80 \text{ KN/m}$$

5.3. Finite Element Analysis:

Most of these processes are described using Partial Differential Equations (PDEs). To solve these PDEs numerical techniques have been developed over the last few decades and one of the prominent ones, today, is the Finite Element Analysis. A numerical technique that cuts the structure of an object into several elements, and then reconnects the elements at points called nodes. The FEM creates a set of algebraic equations which engineers, developers can use to perform finite element analysis.

For the analysis of this foundation the linear FEA on CSI SAFE and Non-linear FEA on ABACUS is performed with given material, boundary and loading conditions.

The linear analysis was performed on commercially used software CSi SAFE version 2016. The analysis was conducted by modelling the geometry of the footing. The material for C40 was

defined as per the properties defined in the Table 1. The loading of the footing was applied on the footing modeling the load as static uniformly distributed load. The bearing capacity was assumed to be 200 KN/m² and the soil was modeled in the software by providing modulus of subgrade corresponding to 25mm deflections as recommended by BS standards.

The nonlinear analysis was performed in ABAQUS. The profile and geometry of the foundation was initially defined. The nonlinear material model was defined using the concrete damage plasticity (CDP) for both compression and tension. The CDP parameters are summarized in table 4 and 5.

Table 4. Parameters of CDP model

Dilation angle	Eccentricity	fbo/fco	K	Viscosity parameters
40	0.1	1.16	0.667	0

Table 5. The plastic parameters of CDP

COMPRESSION CONCRETE PLASTICITY MODEL (CDP)					
σ_c	ϵ_c	d_c	ϵ_{oc} elastic	ϵ_{oc} inelastic	ϵ_{oc} plastic
0	0	0	0	0	0
26.87966637	0.001075129	0	0.001075129	0	0
39.07290547	0.002689569	0	0.001562832	0.001126736	0.001126736
38.28855753	0.003108618	0.020001	0.00153146	0.001577158	0.001545902
36.85088465	0.003851153	0.056798	0.001473956	0.002377197	0.002288437
35.15593951	0.004373266	0.100181	0.001406162	0.002967104	0.00281055
33.52688949	0.004814526	0.141876	0.001341004	0.003473522	0.00325181
31.44066546	0.005468998	0.195273	0.001257559	0.004211438	0.003906281
29.94025157	0.006020469	0.233677	0.001197546	0.004822923	0.004457753
12	0.007	0.692859	0.000479974	0.006520026	0.005437284

TENSION CONCRETE PLASTICITY MODEL (CDP)					
σ_c	ϵ_c	d_c	ϵ_{oc} elastic	ϵ_{oc} inelastic	ϵ_{oc} plastic
0	0	0	0	0	0
3.5	0.000138942	0	0.000139992	0	0
0.146793519	0.001469832	0.958058995	5.87143E-06	0.001463961	0.00132984

Alongside, the soil profile was also modeled in ABAQUS by using the parameters defined in table 3. The soil was assumed to be uniform to a depth of about 1m. The soil was assumed to be dry and the water table being way below the surface. The loading was applied on the footing as described above in section 5.2. The load was applied as static, and the model element was kept as 3D stresses. The non-linearity was considered using meshing at a distance of about 100 mm.

6. Results:

The results of the linear FEA show that the maximum displacement for the footing under applied loadings is around 25mm while the maximum moment is around 22 KN-m which is safe as per moment curvature curve. But the maximum deflection allowed for a footing is about 25 mm so the footing is vulnerable to settlement failure. The results of linear elastic model are summarized in figure 5

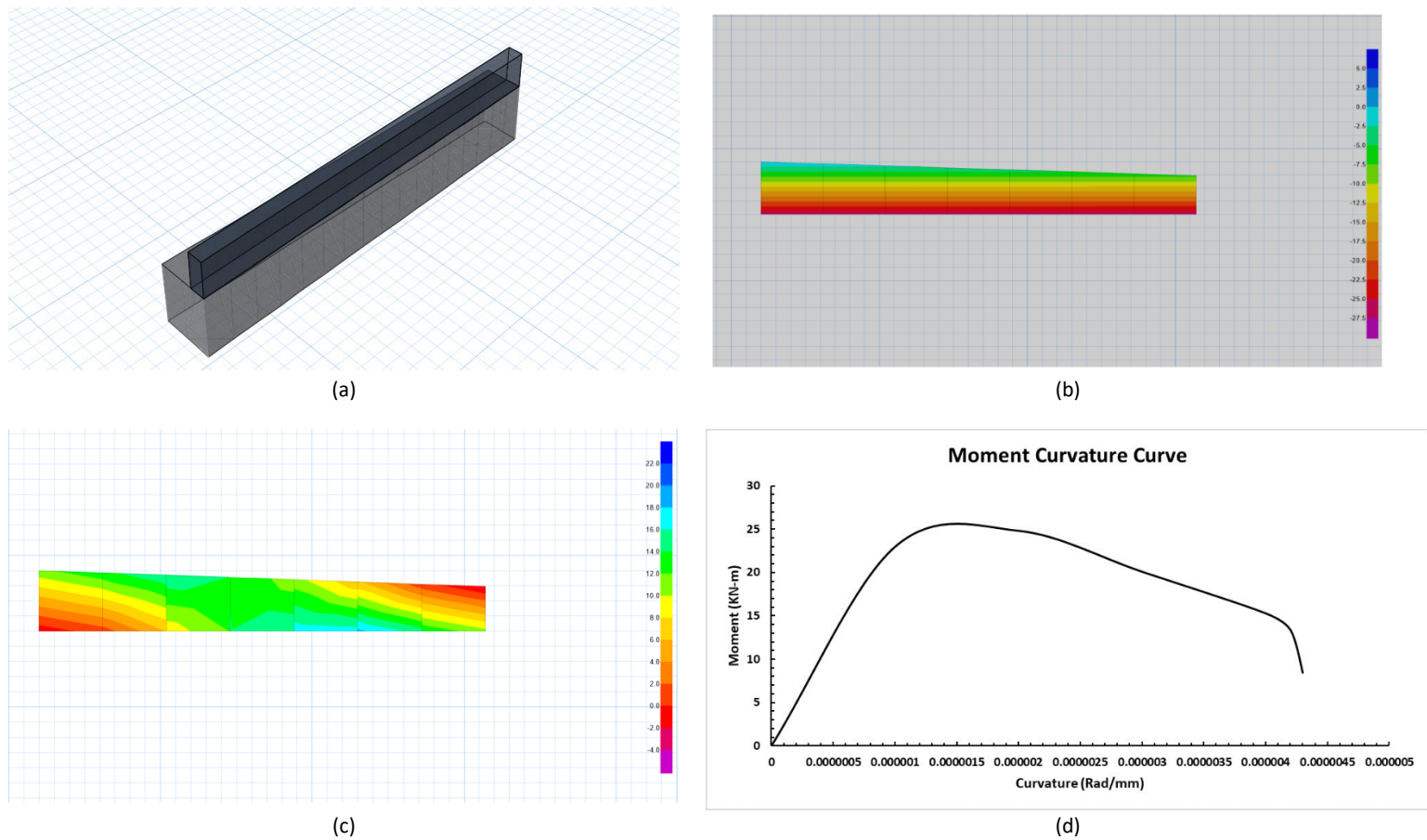


Figure 5. Results of CSI SAFE (a) model developed (b) displacements in mm (c) Moment Demands (d) Moment Curvature curve of footing without reinforcements

The results of detailed nonlinear FEA conducted on ABAQUS are summarized in figure 6. This clearly shows that maximum of about 2.47 MPa of tensile stresses are generated in the model under applied loading. Which is also safe under the tensile capacity of about 3 MPa.

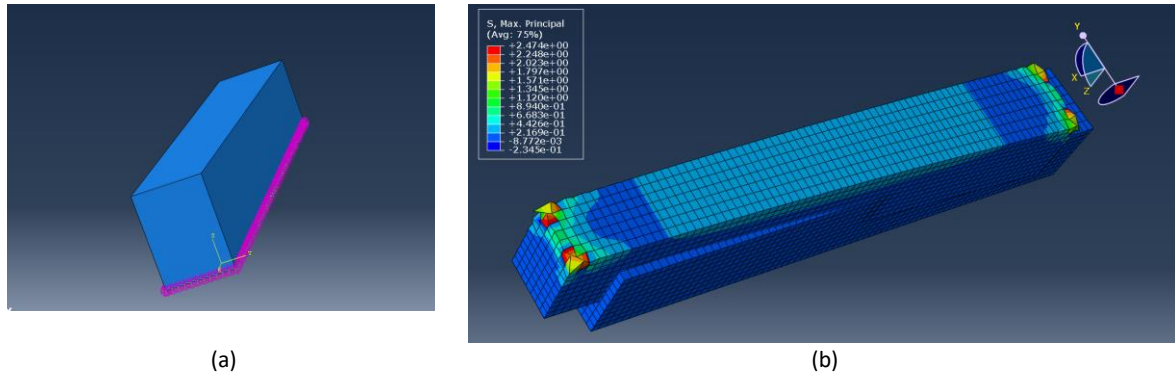


Figure 6. Results of ABAQUS simulations (a) developed model (b) Principal stresses

7. Conclusions:

A detailed linear and nonlinear FEA was conducted on a footing and from that following conclusions were made:

- The footing is safe with given gravity loads applied from the wall and beams.
- The footing can support the applied gravity load with additional double factor of safety. Which means if loads exceed the considered value (80KN/m) then members like steel beam will fail but not the footing.
- As per moment demand and moment curvature curves the footing is safe against gravity load by considering the tensile capacity of concrete
- The footing constructed is not as per code guidance as it recommends the minimum reinforcement for this case, but however considering a minimum of 3MPa tensile capacity of concrete this gravity load can easily be resisted.

8. Recommendations:

The footing is safe under given condition, however following recommendations are proposed to the client.

- Detailed geotechnical and material testing shall be conducted to ensure that the values are greater than those assumed in this investigation. Also, if the values are lower, then footing may be vulnerable to failure and should be redesigned.