Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/04/jls.htm
2015 Vol. 5 (S4), pp. 545-553/Zamani and Rozbahani

Research Article

STUDY OF LOADING CAPACITY OF DEEP PILES NEAR TO SOILED GABLE ROOF

Milad Zamani and *Mazaher Rozbahani
Department of Civil, Malayer Branch, Islamic Azad University, Malayer, Iran
**Author for Correspondence*

ABSTRACT
Determination of loading capacity of piles near to gable roofs is an important subject that geotechnical engineers have speculated on its aspects. If the piles have been made near to the gable roof, they could be influenced by reduction effects of gable roof on the loading capacity. If there are reduction factors similar to the factors of surface foundations, the loading capacity of the pile near to gable roof could be achieved, also when loading capacity of pile in plane grounds was found and the reduction factors were applied. In this research, the effect of a gable roof on loading capacity of piles near to the gable roof will be studied and discussed through Finite Element Method. The research variables are composed of parameters such as L (length of pile), H (height of gable roof), B (distance of pile up gable roof) and b (diameter of pile).

Keywords: *Loading Capacity, Soiled Gable Roof*

INTRODUCTION
Piles are used increasingly to bear axial and lateral loads on structures such as telecommunication towers, tall buildings, power plants, bridges, highway and railroad structures.
Many telecommunication towers, tall buildings and bridges in highway roads and railways are located near steep slopes which their load shall be tolerated by pile foundations and in some cases these piles are affected by the groundwater flow. Location of foundation adjacent to or on soiled gable roofs sometimes is undesirable also determination of loading capacity of these piles near to gable roofs is an important issue from viewpoint of geotechnical engineers.
To determine the effect of parameter L (length of pile), H (height of gable roof), B (distance of pile to gable roof) and b (diameter of pile) on pile loading capacity, the pile loading capacity in both cases of flat land and near to gable roof in similar circumstances has been calculated through use of their Load-Settlement Curves; then ratio of pile loading capacity near to gable roof was evaluated. So in order to influence the outcome of all parameters, distance of pile to gable roof is equal to this distance to its dimensional section (dimensionless distance of pile from the roof), i.e ratio of B/b, as well as ratio of pile length as ration of this length to height of roof (dimensionless length of pile) i.e ratio of L/H.
In this study, the distance from top of gable roof has been increased until pile loading capacity adjacent to gable roof has reached to maximum value, i.e it reaches loading capacity in reference case. By this distance, reduction effects on pile loading capacity are not significant; in fact, loading capacity in reference, in relation to loading capacity in real, reaches to 1.
So far, many studies have been carried out in regards to determine loading capacity of deep foundations in flat lands; and always these values has been reduced inaccurately, so they were considered as loading capacity of deep foundations near to gable roofs that were not cost-effective. Through more accurate researches, behavior of loading capacity of deep foundations near to gable roofs, by the use of finite element method, some coefficient with sufficient accuracy could be obtained. These coefficients are then applied to loading capacity of deep foundations near to gable roof, and then an acceptable loading capacity would be achieved that is cost-effective for Civil Projects.

MATERIALS AND METHODS
Numerical Finite Element Method
This method was introduced since 1956 and was used in the field of science and engineering works such as modeling and analysis of pile foundations in soiled lands. Any mechanical problem that is defined by a

differential equation can be solved using this method. During 1970s, the finite element method has been used for modeling and analysis of nonlinear structures.

Modeling and analysis by the use of finite element method consist of six stages as follows:

1) Making discrete and division of structure into smaller elements
2) Select the interpolation functions to obtain approximate solution of unknown elements
3) Formation of the stiffness matrix and nodal force vector for elements
4) Formation of stiffness matrix and nodal forces vector to form the equilibrium equations
5) Applying boundary conditions and solve these equations to obtain total nodal displacements vector
6) Calculate strain and stress of elements using nodal displacement vector and behavioral model

Software Plaxis 3D Foundation

Known Moher-Coulomb Model is a non-linear, robust and simple model that it can be considered as a first estimate of actual behavior of real stone or soil. Moher-Coulomb Model is used to calculate actual ultimate loads and reliability coefficient. This elasto-plastic model consists of five fundamental parameters including Module Yang E, Poisson's ratio ν, internal friction angle φ, cohesion C and dilation angle ψ. Moher-Coulomb Model includes a yielding function which represents a yielding level in stresses which follow this area, and soil behavior is elastic completely and Hooke 's law of elasticity is followed by E and ν.

When stress level reaches to yielding level, plastic deformations will begin. (It should be noted that the dilation angle is needed to model irreversible increase in the size of shear volume) Terms of yielding could be defined through three yielding functions in terms of the main stresses, as follow:

$$f_1 = \frac{1}{2}\left|\sigma'_2 - \sigma'_3\right| in\ \phi - c + \frac{1}{2}(\sigma'_2 + \sigma'_3)\ \mathrm{Sin}\ \phi - c\cos\ \phi \leq 0$$

$$f_2 = \frac{1}{2}\left|\sigma'_3 - \sigma'_1\right| + \frac{1}{2}(\sigma'_3 + \sigma'_1)\cos\ \phi \leq 0$$

$$f_3 = \frac{1}{2}\left|\sigma'_1 - \sigma'_2\right| + \frac{1}{2}(\sigma'_1 + \sigma'_2)\mathrm{Sin}\ \phi - c\cos\ \phi \leq 0$$

These yielding functions give an irregular hexagonal pyramid among the main stresses as shown in Figure 1 (the main stresses of σ_1 ،σ_2 و σ_3 in the directions of Z, Y, X).

Numerical Modeling by Software Plaxis 3D Foundation

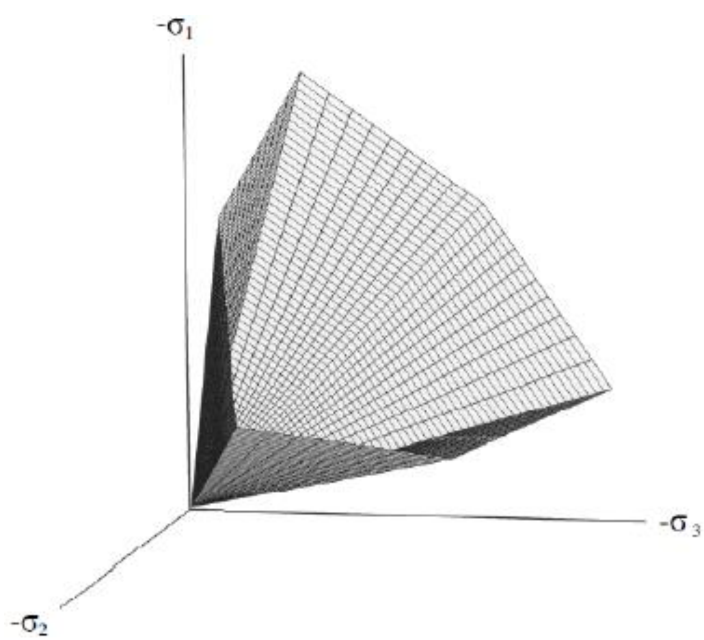

Figure 1: Yielding level of Moher-Coulomb Model

Failure function of Moher-Coulomb Model is generally to estimate dilation. So it is considered as a potential function that is the plastic strain rate proportional to the derivative of the potential function in regards to stresses; therefore according to Orthogonality Law, plastic strain is perpendicular to potential function. For simplicity we assume that this function is similar to Moher-Coulomb Model, but ψ is used instead of φ. This parameter is used to model volumetric plastic strain samples in compacted soils. Thus, three potential plastic functions for Moher-Coulomb Model are defined as follow:

$$g_1 = \frac{1}{2}|\sigma'_2 - \sigma'_3| + \frac{1}{2}(\sigma'_2 - \sigma'_3)\,\mathrm{Sin}\,\Psi$$

$$g_2 = \frac{1}{2}|\sigma'_3 - \sigma'_1| + \frac{1}{2}(\sigma'_3 - \sigma'_1)\,\mathrm{Sin}\,\Psi$$

$$g_3 = \frac{1}{2}|\sigma'_1 - \sigma'_2| + \frac{1}{2}(\sigma'_1 - \sigma'_2)\,\mathrm{Sin}\,\Psi$$

In regards to influence of various parameters on the results of analysis; in this section, we tried to use the perfect and effective parameters and expressed them briefly by software. Figure 4-1 shows the geometry and conditions of the model. The length of grid is 50 times of pile section and its width is 30 times of pile section. For modeling of pile and soil, an element with 15 nodes is used.

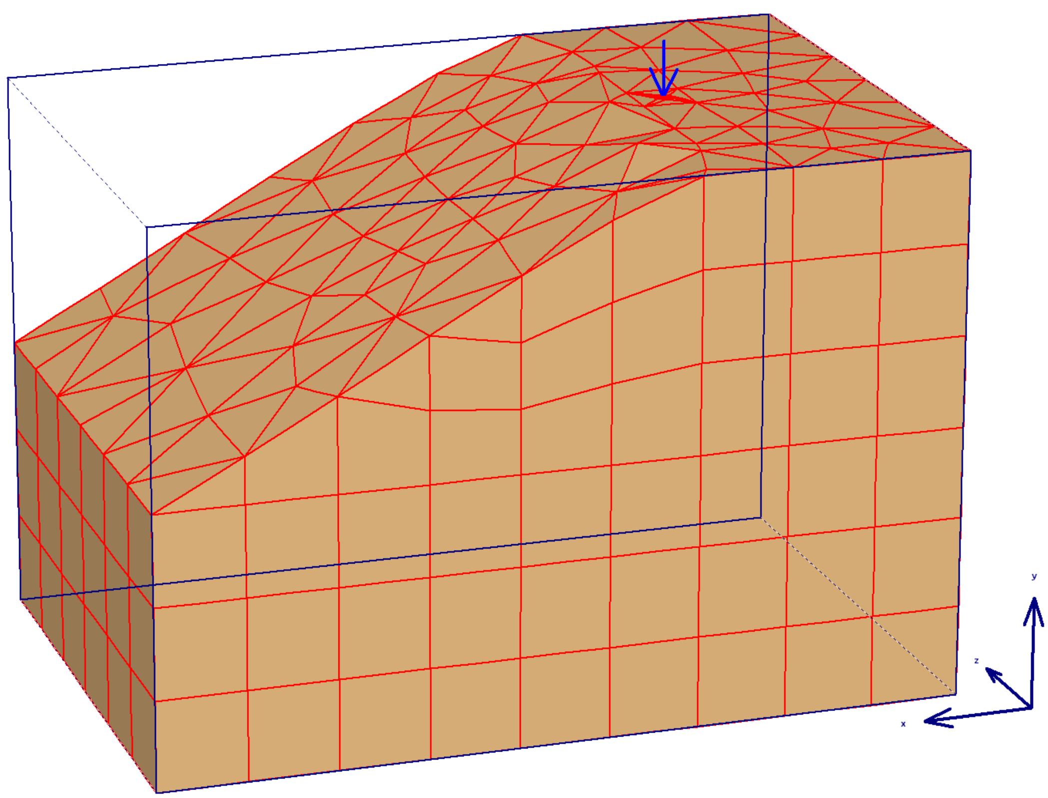

Figure 2: Software meshing and loading screen

In this study, concrete piles and their behavior models are elastic. Software Plaxis 3D Foundation can define nonlinear behavioral model through Moher -Coulomb Model. So soil behavior model is considered based on Moher -Coulomb Modelin order to show elasto-plasticity behavior of soil. The properties of soil and pile are presented in Table 1 and 2.

Table 1: Parameters and Materials of pile

Parameter	Type	Strip footing	Unit
Materials	Behavior	Linear	-
Foundation width	B	1	M
Special weight	EA	$5*10^6$	KN/m
Yang Module	EI	8500	$KN/m^2/m$
Poisson ratio	V	0/3	-

Table 2: Parameters and Materials of soil

Parameter	Title	Clay	Unit
Material	Model	MC	-
Behavior of materials	Behavior type	unDrained	-
Special weight	γ_{unsat}	17/5	KN/m^3
Saturation weight	γ_{sat}	17/5	KN/m^3
Yang Module	E_{ref}	12000	KN/m^3
Poisson ratio	V	0/3	-
Cohesion	C_{ref}	40	kPa
Angle of friction	φ	0	0
Angle of dilation	ψ	0	0
Reducer factor of joint level	R	1	-

Validation of Study

To validate the modeling and numerical analysis and software, loading test of a Bored Pile has been carried out and simulated in Brazil, then the results were in conformity with measured data. In this test, a pile with a diameter of 40 cm has placed in the center a cavity (excavation) under load of 400 KN. Top point of pile as much as 60 cm was higher than bottom of cavity.
According to Fig. 4-2 this pile is placed in clayed sand and silty sand and level of water is lower than pile.

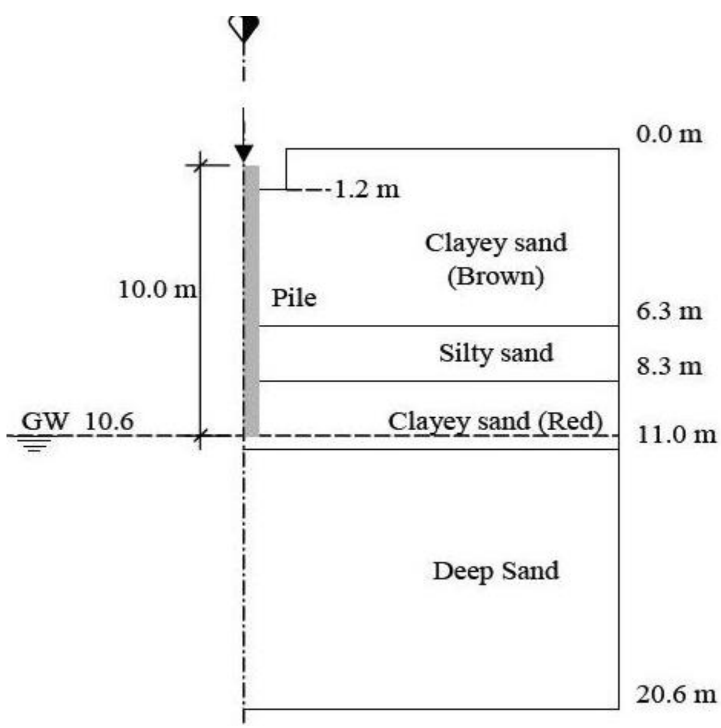

Figure 3: Cross-section of study site

Soil Properties in Study Site

Property	Layer 1	Layer 2	Layer 3	Layer 4	Pile
Model	MC	MC	MC	MC	LE
$\gamma_{sat}(kN/m^3)$	16.7	18.8	19.8	19.8	24
$\gamma_{unsat}(kN/m^3)$	16.7	18.8	19.8	19.8	-
$E(MN/m^2)$	9.15	13.51	13.57	19.3	29200
ν	0.12	0.12	0.07	0.05	0.3
c (kN/m^2)	13	12	14	17	-
$\phi(\circ)$	26	23	23	23	-
$\psi(\circ)$	0	0	0	0	-
R_{inter}	1	1	1	1	1

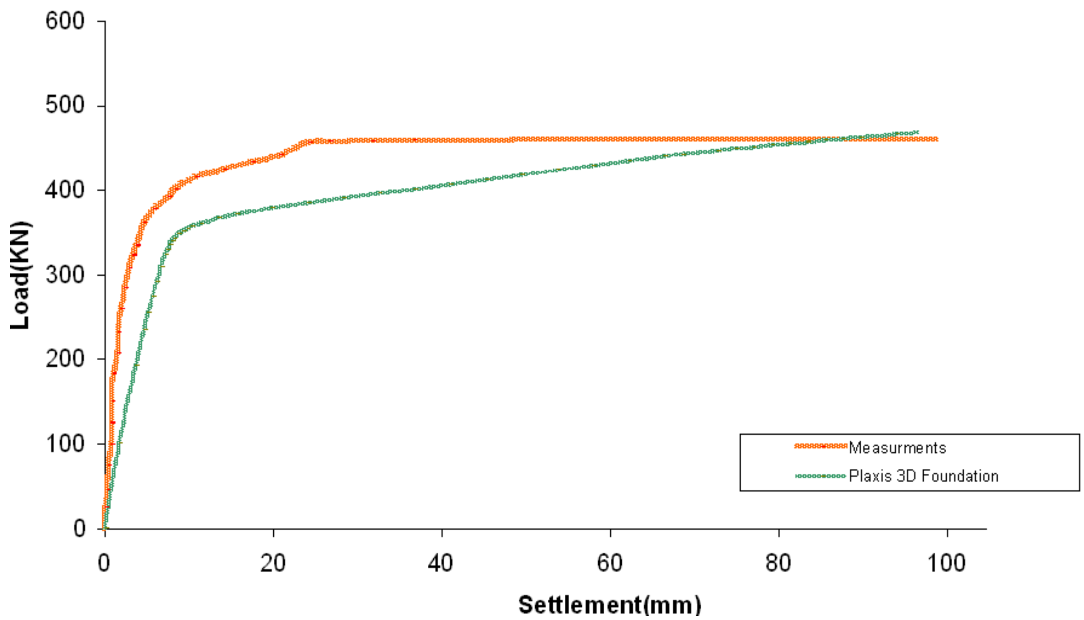

Figure 4 shows load-settlement curve resulted by loading test and numerical analysis of finite element by Software Plaxis 3D Foundation

As can be seen, the results of Software Plaxis 3D Foundation are reasonably consistent with the reference model. By the way, modeling, meshing and defining of soil and pile elements can be reliable for the further models.

Since the objective is to evaluate the effect of trenches perpendicular to the pile loading capacity, so the other conditions should be similar for both original model (Piles near to gable roof) and the reference model (pile on the horizontal ground level).

For this purpose, models were built desirably and were meshed. At first models were applied under geostatic loads in order to take place the natural ground conditions, and then they were applied by the vertical load (2000 KN).

***The Effect of Pile Spacing From Top of Gable Roof and Effect of Pile Length on Pile Loading Capacity*:**

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/04/jls.htm
2015 Vol. 5 (S4), pp. 545-553/Zamani and Rozbahani
Research Article

To determine the effects of L (length of pile), H (height of gable roof), B (pile spacing up to gable roof) and b (diameter of pile) on pile loading capacity, loading capacity shall be calculated in both flat land and adjacent gable roof in the same conditions and by the use of load- settlement curves and pile loading capacity near to gable roof will be studied. So in order to influence the outcome of all parameters, distance of pile to gable roof is equal to this distance to its dimensional section (dimensionless distance of pile from the roof), i.e ratio of B/b, as well as ratio of length of pile as ratio of this length to height of roof (dimensionless length of pile) i.e ratio of L/H. Gable roof sections and geometric properties of model are given in Figure 6-4.

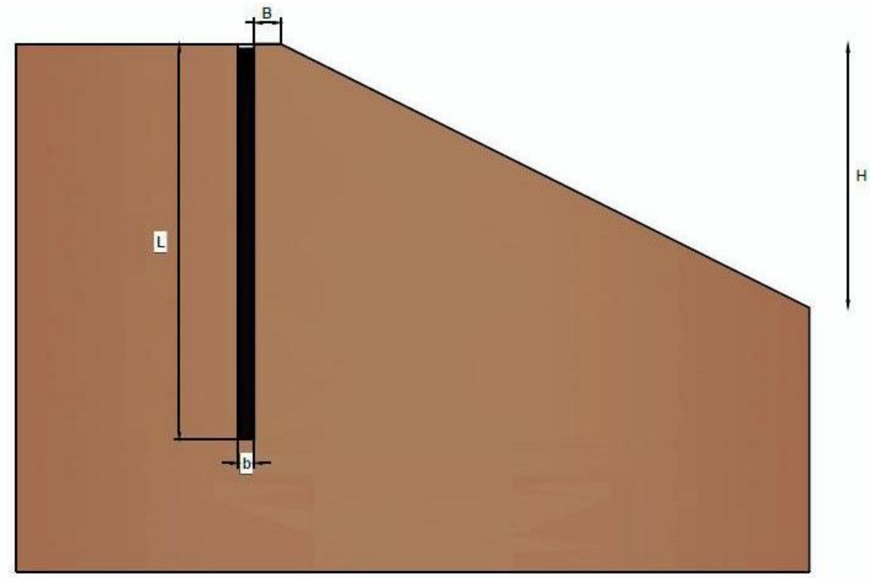

Figure 6: Cross section of gable roof and define geometry of model

Study of Effect of Pile Spacing From the Gable Roof on Pile Loading Capacity
To evaluate the effect of parameters B, b, L and H on the pile loading capacity and settlement of piles, several of these parameters should be taken into consideration and analyzed.

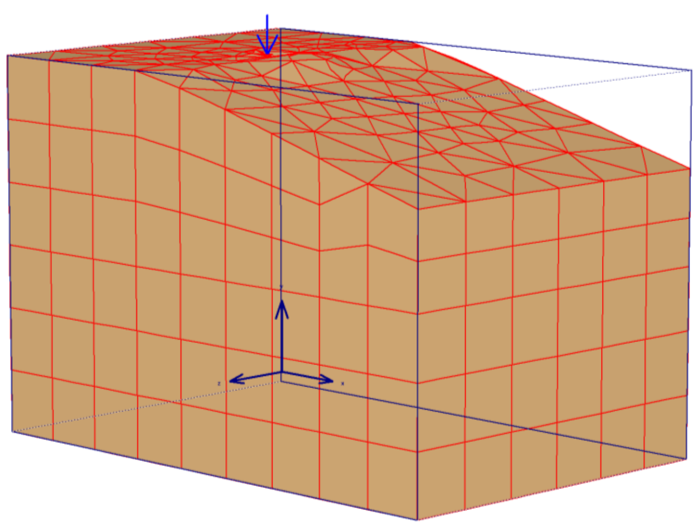
Figure 7: 3D Modeling of loading and slope
The ratios are presented in Table 4-4. Stages of change in B/b will continue until pile loading capacity values adjacent to the slope are closed to pile loading capacity in the flat land.

Table 4: Properties of gable roof

Ratio of $\frac{B}{b}$ (ratio of pile spacing from top of slope to diameter of pile)	**Ratio of $\frac{L}{H}$ (ratio of length of pile to height of slope)**
0	2
0/5	2
1	2
1/5	2
0	1/33
0/5	1/33
1	1/33
1/5	1/33
0	1
0/5	1
1	1
2	1
2/5	1
0	0/8
0/5	0/8
1	0/8
2	0/8
3	0/8
4	0/8

The Effect of Pile Spacing from Top of the Gable Roof (B/B):

In this study, pile spacing from top of gable roof is introduced as ratio of this space to its dimensional section (dimensionless distance of pile from the roof), i.e ratio of B/b, and length of pile as the ratio of this length to height of gable roof (dimensionless length of pile), i.e ratio of L/H.

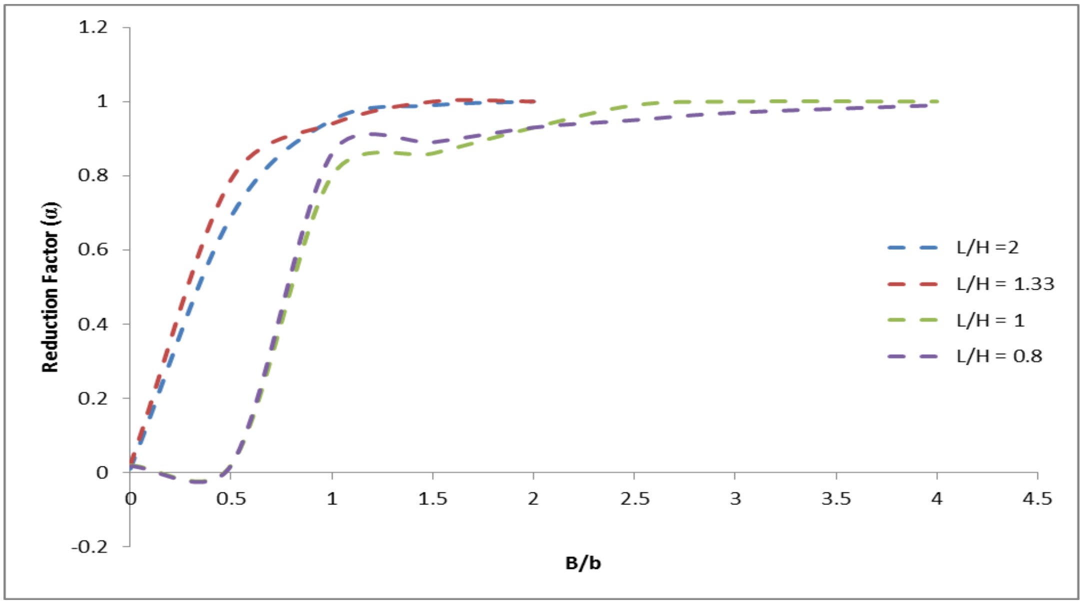

Figure 8: Changes of α curve toward dimensionless pile spacing of gable roof (B/b)

In order to review and analyze sensitivity of reduction factor α relative to dimensionless distance of B/b, variables of this factor will be calculated based on different B/b and dimensionless lengths of piles; so the

results are shown by the following curve. Pile spacing from top of gable roof would be increased until loading capacity near to gable roof reached to maximum rate, i.e it is equal to loading capacity in reference case. It is a distance in which reduction effect of gable roof on loading capacity is not significant and in fact, reduction factor α reaches to 1. Thus, the reduction factor α values in terms of certain distances from top of roof has been fixed up to minimum distance in which gable roof can not affect on loading capacity significantly (a neutral distance).
As can be seen in Figures, the increase in the ratio B/b leads to soften slope of L/H curves. In the range of B/b lower than 1, changes of coefficient α is significant. But with the passage of this slope, the curve becomes more uniform that verifies existing of loading capacity in reference case.

Effect of Dimensionless Ration of Length of Pile (L/H)

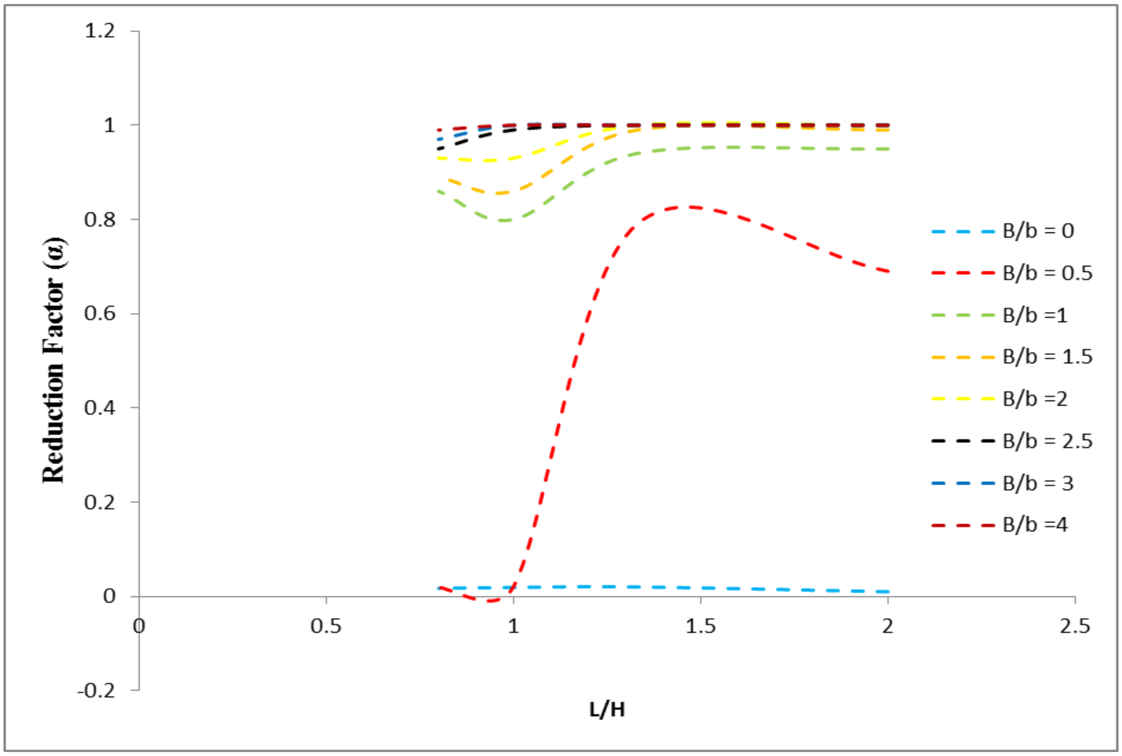

Figure 9: Changes of α curve toward dimensionless length of pile (L/H)

To analyze the sensitivity of the reduction factor α to L/H, the values of these quantities for L/H varies, and it is calculated in regards to dimensionless distance of pile from gable roof and the results are presented in Figure 9.
As can be seen in the curve, by increasing the length of pile, loading capacity becomes maximum i.e the loading capacity will reach to reference case. Changes in the scope of reduction factor α is more expanded in piles with dimensionless shorter length; and if ratio of L/H is increased, the range of variation will be reduced, so effect of gable roof on pile loading capacity with dimensionless shorter length will be increased.

Values of Reduction Factor A

In this study, through analysis of different models with different geometries in a pile near to the gable roof, Software Plaxis 3D Foundation evaluates the reduction of loading capacity compared to the reference case. At the end of each stage of modeling and analysis of the results, reduction factors of pile resistance have been extracted and are presented in Table 4-24.

Table 5: Reduction factor α

$\frac{L}{H}$ \ $\frac{B}{b}$	**0**	**0/5**	**1**	**1/5**	**2**	**2/5**	**3**	**4**
2	0/01	0/69	0/95	0/99	1	-	-	-
1/33	0/02	0/79	0/94	1	-	-	-	-
1	0/019	0/02	0/8	0/86	0/93	0/99	1	-
0/8	0/017	0/019	0/86	0/89	0/93	0/95	0/97	0/99

As seen in Table 5, we see that if ratio of L/H increases, ratio of B/b will increase, and pile reaches to reference case with more spacing toward loading capacity.

RESULTS AND DISCUSSION

According to studies the following results has been conducted:
1. The reduction factor α plays an important role in determining the pile loading capacity near to the slope.
2. Reduction effect of gable roof on the pile loading capacity with a dimensionless length is more intuitive.
3. The ratio L/H<1, the minimum slope distance should be equal to the diameter of pile in order to achieve minimum loading capacity, but for ratio L/H>1, minimum pile capacity is equal to half of the diameter of pile.
4. Increase of ratio B/b causes to soften the slope of curve L/H. In the range of B/b lower than 1, changes of coefficient α is markedly visible; but with the passage of slope of curve, the curve becomes more uniform which shows loading capacity in reference case.
5. In general, if the length of pile increases, loading capacity will become to maximum rate, i.e it reaches to reference case. Changes in the scope of reduction factor α of piles with dimensionless and shorter length are wider, and if ratio L/H increases, the range of variation will reduce, so the impact of gable roof on loading capacity of piles with shorter dimensionless length is higher.
6. Partially offset distance means the minimum distance in which the other gable roof does not affect on loading capacity of piles and depends on dimensionless length of pile, so if the length is smaller, the distance is greater. For example, we have B/b = 4 in terms of L/H = 0.8 and B/b=3 in terms of L/H=0.8.

REFERENCES

Building and Housing Research Center (2005). *Code for Seismic Design of Buildings 2800*, third edition.
Deputy of housing and urbanization (2013). 10th section of National Regulations of Housing “Design and Construction of Steel Stuctures”
Filiatrault A and Cherry S (1990). SeismicDesign Spectra For Friction-Damped Structures. *Journal of Structural Engineering* **116**(5).
Keyvani Jafar-Rahimi Mahdi (2011). Strengthen of structures with dampers” and Civil publication of Improvement no.10
Liao Wen, Mualla Imad and Loh Chin (2004). Shaking table test of a friction damped frame structure. *The Structural Design of Tall and Special Buildings* **13** 45–54
Mualla IH (2000). Experimental and computational evaluation of a novel friction damper device. PhD thesis, Department of Structural Engineering and Materials, Technical University of Denmark.
Mualla Imad and Bellev Borislav (2002). Performance of steel frames with a new friction damper device under earthquake excitation. *Engineering Structures* **24** 365–371.