Comparison of skin friction of pile in axial direction from pull out and in torsional direction from torsion test

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILLMENT OF REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF
MASTER OF TECHNOLOGY
IN

GEOTECHNICAL ENGINEERING

Submitted by:
ASHWANI
(2K16/GTE/06)

Under the supervision of
Dr. Naresh kumar
(Professor, Department of CE, DTU)

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042
June 2018

CANDIDATE'S DECLARATION

I do hereby certify that the work presented is the report entitled "**Comparison of skin friction of pile in axial direction from pull out and in torsional direction from torsion test**" in the partial fulfillment of the requirement for the award of the degree of "Master of Technology" in Geotechnical Engineering submitted in the Department of Civil Engineering, Delhi Technological University, is an authentic record of my own work. I have not submitted the matter embodied in the report for the award of any other degree or diploma to any other institution.

(Ashwani)

(2K16/GTE/06)

CERTIFICATE

This is to certify that major report entitled "**Comparison of skin friction of pile in axial direction from pull out and in torsional direction from torsion test**" work carried out in fulfillment of the requirements for the award of Master of Engineering (Geotechnical Engineering), department of Civil Engineering, Delhi Technological University, Delhi.

Dated: **Ashwani**

Roll no: 2K16/GTE/06

It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

Dr. Naresh Kumar

Civil Engineering Department,
Delhi Technological University, Delhi

ACKNOWLEDGEMENT

I am extremely grateful and thankful Prof. Nirendra Dev, Head of Civil Department for his corporation. Finally I express gratitude to my family for their love and encouragement. I have received so much personal support from family and friends.

DATE: -

ASHWANI

2K16/GTE/06

Contents

ABSTRACT

Skyscraper buildings, Bridges, Flyovers play a key role in urban approach and regeneration. These massive structures have mainly pile foundation. Pile foundation carry combinations of vertical, torsional and lateral forces. Vertical force on pile due to its own weight of structure. Lateral force on pile due to horizontal movement of soil. Torsional force on pile due to wind action and unusual force act on edge of structure that tends to rotate a body around its axis.

There is no specification for torsional force acting on pile in IS 2911 Part-4.Torsional force factors should be added in IS 2911. Skin friction on pile play a key role in pile foundation. Skin friction factor resist the moment of pile against torsion and uplift forces.

Therefore, objectives of this work are:

- Mechanism of applying load for pull out test.
- Mechanism of applying torque for torsion test on piles.

A mechanism of applying load for pull out test at different length of pile. At different length skin friction factor from pull out is nearly equal. There is also a mechanism of applying torque for torsional test on pile at different length. Skin friction factor is also find out in torsional test. Through pile pull out mechanism and torsional mechanism we are trying to find out a relation of skin friction factor.

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INTRODUCTION

Foundation is a part of structure which transfer structural load to the soil. Pile foundation is a type of deep foundation. High rise buildings, bridges, flyovers, electric transmission towers all have pile foundation. Pile foundation transfer the load of structure by end bearing, friction and both. End bearing pile transfer the load of structure through bottom end of pile reston layer of hard soil or rock. In friction pile weight of the structure transferred to the adjoining soil by friction between pile and surrounding soil.

Skin friction factor play an important role in friction pile. When a body drags or drives into soil or any medium, the skin friction gets developed on to the surface of the body which resists the further movement of the body into medium, that friction is called skin friction. Skin friction of pile depend upon various factors. Some of main factor which affect skin friction value of pile is surface of pile (material of pile), relative stiffness of soil and driven method of pile. For sustain heavy loads large diameter bored piles are usually used. Piles are mainly bear axial and lateral load. Lateral load from surrounding soil moment and axial load from direct structure.

Every pile foundation structure like bridges have some stress due to torsion, torsion on pile come due to eccentric horizontal loads from wind, high speed vehicles and ship impacts. There is no such provision in IS 2911 for torsion on pile. Lacking in design of foundation against these load lead to terrible consequences.

Chapter 2
Literature Review

2.1 Pull out test on pile {IS : 2911- Part 4 – 1985}[1]

2.1.1 By using a suitable pull out set up uplift force may prefer by mean of hydraulic jack with dial gauge. Hydraulic jack rest on rolled steel joists resting on two support on ground surface is one of the method for pile pull out test. Top of test pile attach to the frame and hydraulic jack react against it. Pile is pull out when jack operated. Reaction transfer to ground through support which are at least 2.5D away from test pile. Reinforcement bars of pile threaded bolt or may be welded to the framework. A central rod design to bear pile load and embedded central in pile to a length equal to bond length load required use as an alternative sometimes. More number of rods should be used for heavier load and rods are in symmetrical manner.

2.1.2 To withstand pulling adequate steel should be in test pile. Additional reinforcement may be necessary in order to allow for neck tension in pull out test.

2.1.3 The safe uplift least of following:

a) For piles up to and inclinding 600mm diameter
.
1) Load displacement curve show a clear break at half of load.

b) For piles more than 600mm diameter

1) Load displacement curve show a clear break at half of load.

2.1.4 Initially test should be carried out until load displacement curve shows a clear break or up to 2.5 times estimated safe load.

2.1.5 12mm total displacement or one and half times the estimated safe load whichever is earlier carried out in routine test.

2.1.6 Mainly pull out test shall be carried on initial test piles. For the following considerations pull out test necessary to conduct:

a) To check the pile shaft is designed to cater for such uplift load.

b) To limit the displacement within elastic deformation of pile beyond which test should be discontinued.

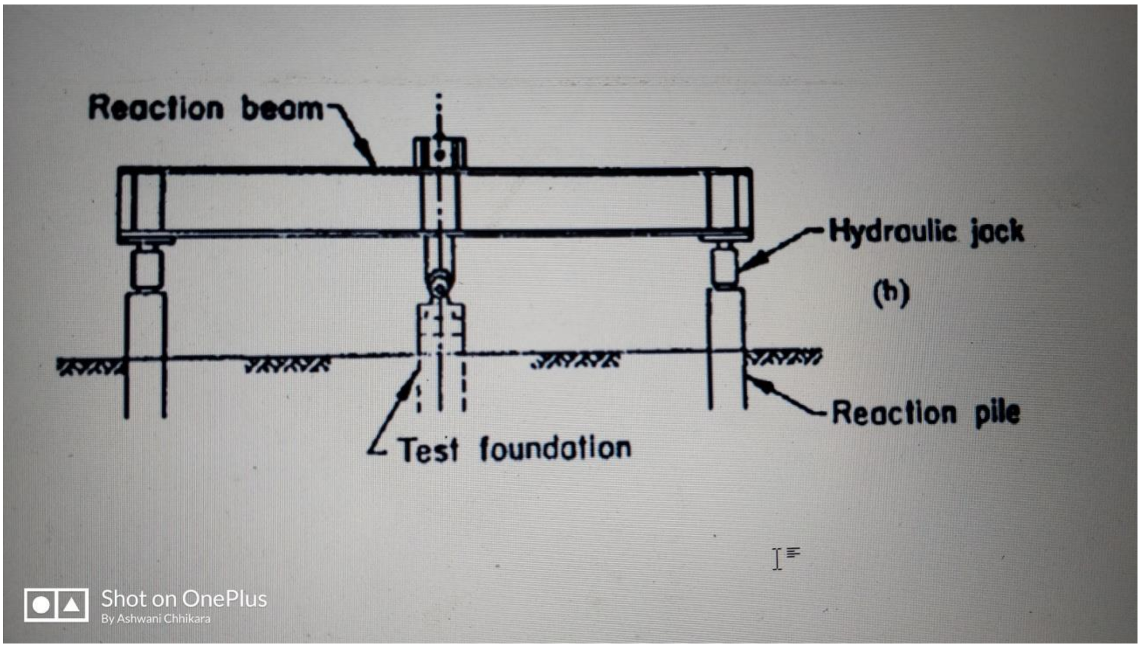


Fig. 2.1 Pile Pull out set up{O'Rourke and Kulhawy, 1985}[2]

2.2. Torsion of circular shaft{nptel.ac.in}[3]

2.3 **Definition of Torsion**: Twisting of a body (rod) by applying a force tending to rotate one end or part about its longitudinal axis while the other side is held fast. For example wrench is using for tighten a nut on a bolt. If wrench, bolt and force all perpendicular to each other, moment is force(F) times length(L) of wrench: T = F.L. N-m is SI unit of torque.

Simple torque: $T = F \times L$

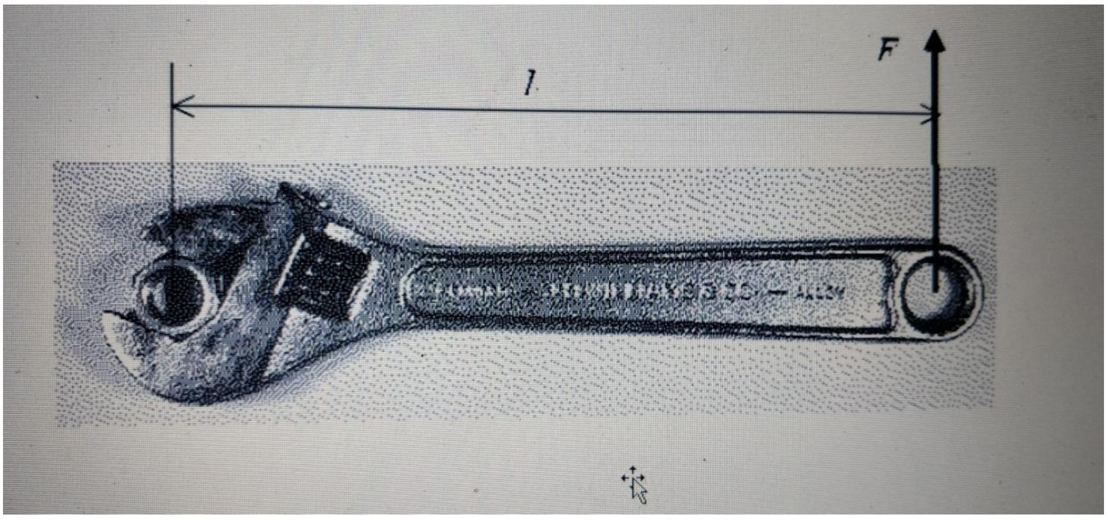


Fig. 2.2 Torsional force acting on nut{David Roylance}[6]

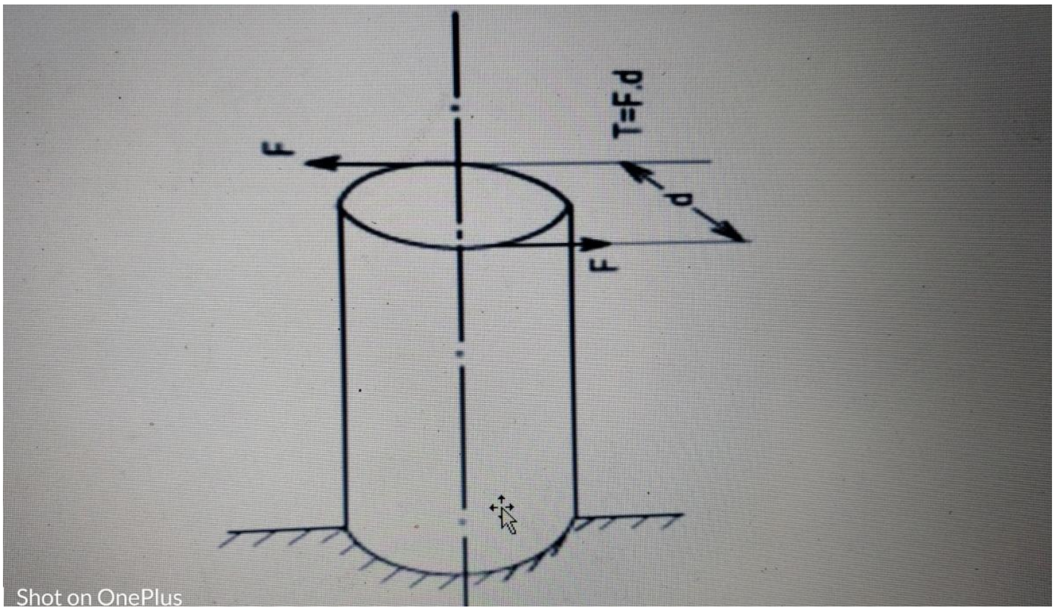


Fig. 2.3 Torsional force acting on circular shaft{nptel.ac.in}[3]

2.4 Generation of shear stresses {nptel.ac.in}[3]

From the figures the phenomena of setting up of shear stresses in a bar might be understood.

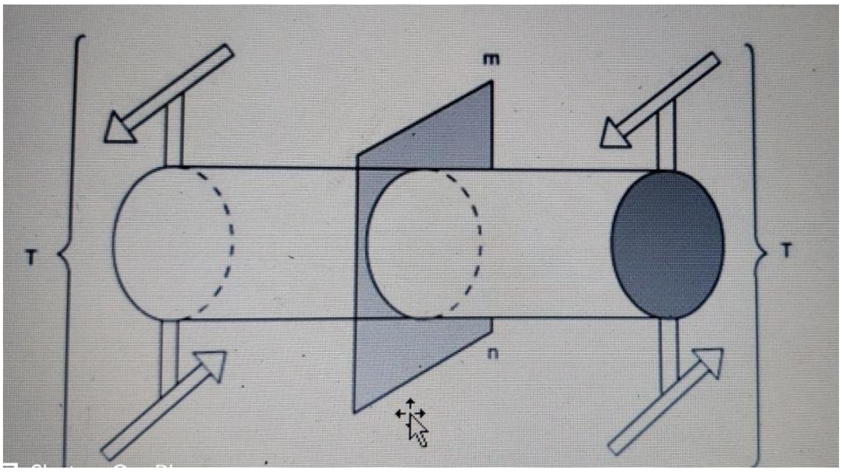


Fig2.4: Here static equilibrium is maintain in bar or a cylindrical member where resultant external torque T is acting on the member. Some imaginary plane "mn" to be cut to the member be imagined. {nptel.ac.in}[3]

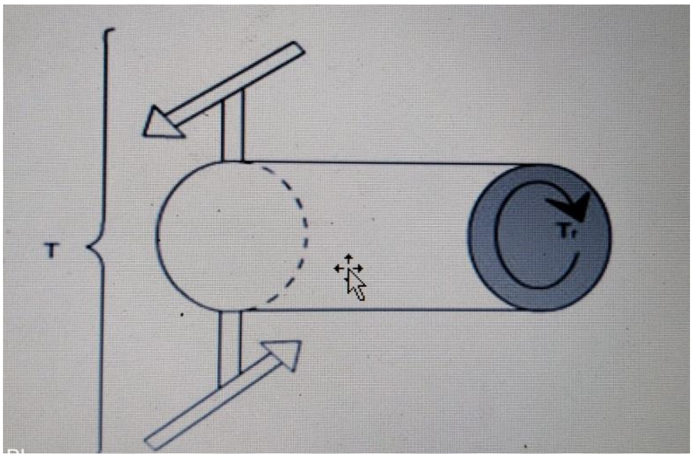


Fig2.5: The portion on R.H.S removes after cut the plane “mn”. Before cut the section entire member in equilibrium so each portion must be in a equilibrium after cut the section. So, the cylindrical member is in equilibrium resisting torque T_r developed due to under the action of resultant external torque. {nptel.ac.in}[3]

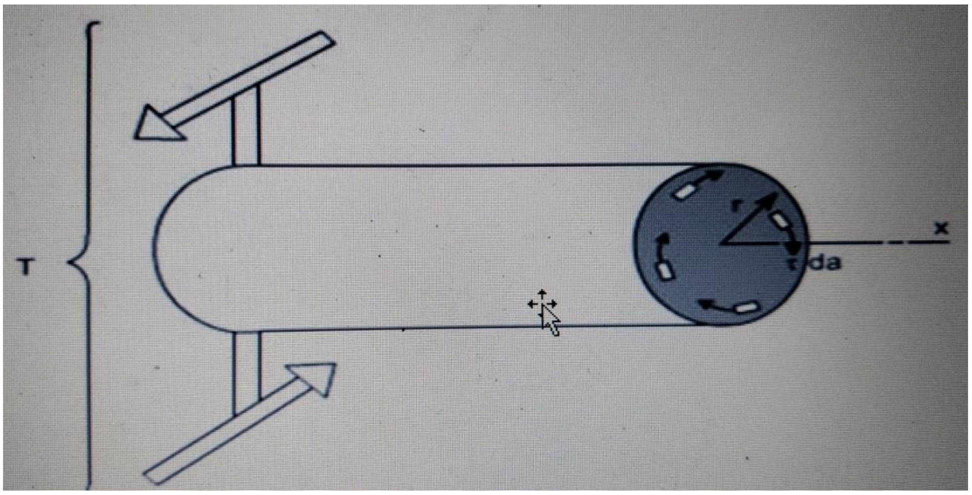


Fig2.6: How resisting torque T_r is developed shows in figure. The Preventing torque T_r is generate by virtue of an enormous mal shear forces acting on the plane vertical to the axis of the cylindrical member. Certainly shear force developed virtue of shear stresses. So, we can say that when we apply torque to a particular member, there will be shear stress acting on any element. Although on other side the reciprocal shear forces come into role. An element of this member subjected to a pure shear due to applying of torque. {nptel.ac.in}[3]

2.7 **Twisting Moment**

The twisting of an object(in this case bar) due to an applied torque is called twisting moment. When a member is subjected to couple, rotational motion about longitudinal axis is produced. Twisting moment is a special case of a bending moment. When one end of a member is twisted and another end is held or move anti-clockwise then this bending moment is called twisting moment. {nptel.ac.in}[3]

2.7 **Shearing Strain**

When we marked a line ab on the surface of the unloaded bar, and then we apply a twisting moment this ab line moves to ab”. $'\gamma'$ is a angle measure in radian between final and initial position of line ab define as shearing strain at the surface of bar.{nptel.ac.in}[3]

‘.

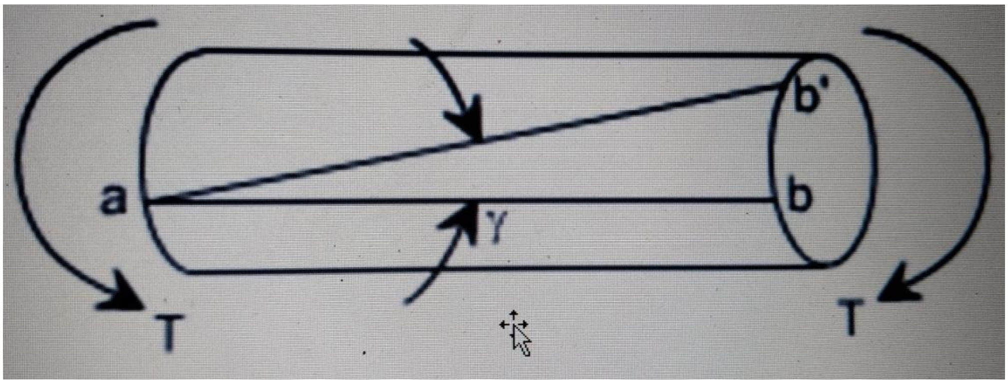


Fig. 2.7 Shaft under torsion showing shearing strain{nptel.ac.in}[3]

2.8 **Modulus of Elasticity in shear**

Modulus of Rigidity OR modulus of elasticity in shear is ratio of shear stress to shear strain. Modulus of elasticity in shear is represent by the symbol of G. Pascal (Pa) is SI unit of modulus of elasticity in shear. {nptel.ac.in}[3]

2.9 **Angle of Twist**

When we subjected a shaft or bar of L length to a constant twisting moment T along its length, than θ is angle through which one end bar twist relative to other is known as angle of twist. θ is radian. {nptel.ac.in}[3]

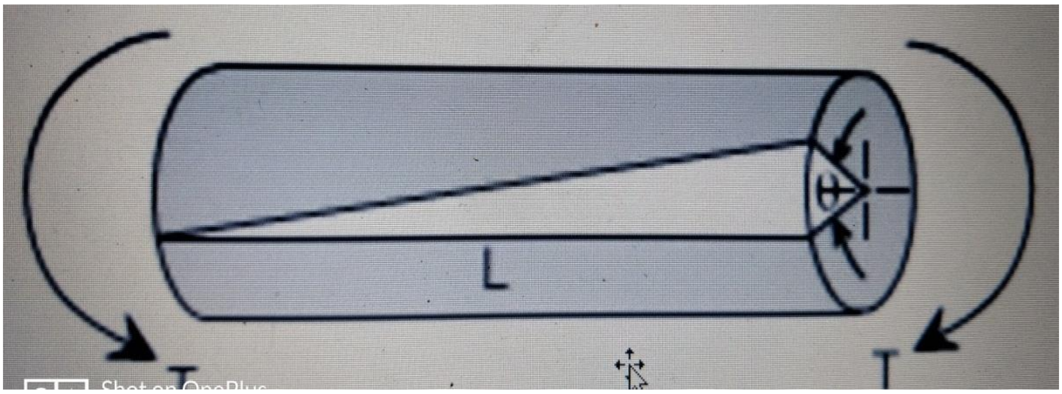


Fig.2.8 Shaft under torsional force{nptel.ac.in}[3]

2.10 **Relationship in Torsion{nptel.ac.in}[3]**

$$\frac{\tau}{R} = \frac{T}{J} = \frac{G\theta}{L}$$

τ = Shear stress (MPa)

R = Radius of cross-section of circular shaft (m)

T = Torsion force (N-m)

J = Polar moment of interia (m^4)

J = $\frac{\pi}{32}(D^4 - d^4)$

D = external diameter

d = internal diameter

G = shear modulus (GPa)

θ = Angle of twist (radian) (1 radian = $\frac{180}{\pi}$ degree)

L = Length of shaft (m)

Chapter 3
Experimental Setup

3.1 Pit Construction

Suitable place is located, in soil mechanics laboratory. Figure 3.1 show real image, cross section plan and side view of pit. Pit was constructed by my seniors Ombir tomar.

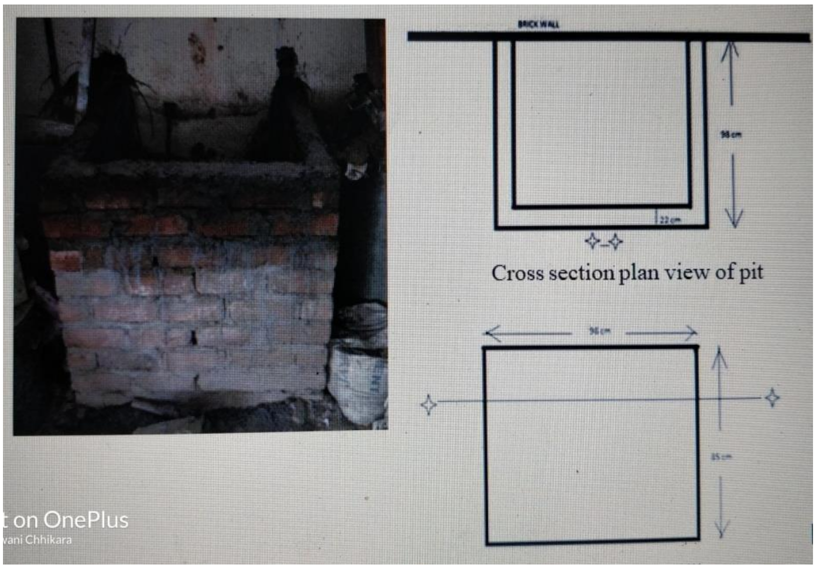


Fig. 3.1 Real image of pit on left side, plan and side view of pit on right side{DTU thesis}[4]

Length, breadth and depth of pit is 98cm, 98cm, and 85cm respectively. Material used for construction of pit was cement, fine aggregates, coarse aggregates and bricks. Only three side of pit was constructed, fourth side was wall of laboratory. Sand used for motar was Yamuna sand.

3.2 **Drying and filling of Yamuna sand in the pit**

Yamuna sand brought from the building material shop near DTU. Pit was filled in three layers with Yamuna sand. First 3 bags Yamuna sand was transfer to site and dry there for 7 day. Dry sand fallen in the pit at the height of 1.5m. For second layer again 3 bags of sand was dried and pit was filled. For last or third layer 4 bags of sand was dried and pit was filled. Pit was almost full by roughly, 1m^3 of Yamuna sand.{DTU thesis}[4]

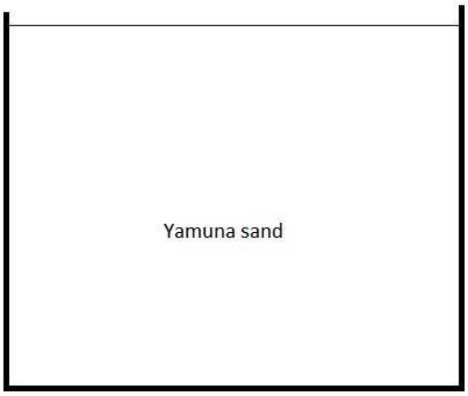


Fig. 3.2 Pit with Yamuna sand

3.3 **Manufacturing of single pile**

Mild steel was used for manufacturing the pile. Mild steel pile had hollow diameter of 30mm or length of 90cm.

Fig. 3.3 Mild steel modal pile of 90cm length{DTU thesis}[4]

At the end of the hollow pile cone of solid steel was attached. Cone helps the pile to driven into the Yamuna sand. With the help of lathe machine and cutter solid cone was made.

Fig. 3.4 Pile of diameter 30mm

3.4 Placing of girders or inclined pulleys

After filling Yamuna sand in the pit, it's time to placing the girders on the wall of the pit. They had used two T- shape steel channel sections. Length of steel channel section was 1.10 m. Each girder was placed on the pit wall and hold fasted about 10 cm inside the laboratory wall. Pulleys were welded with the T-shape channel section at an angle of 45^{o} with vertical.

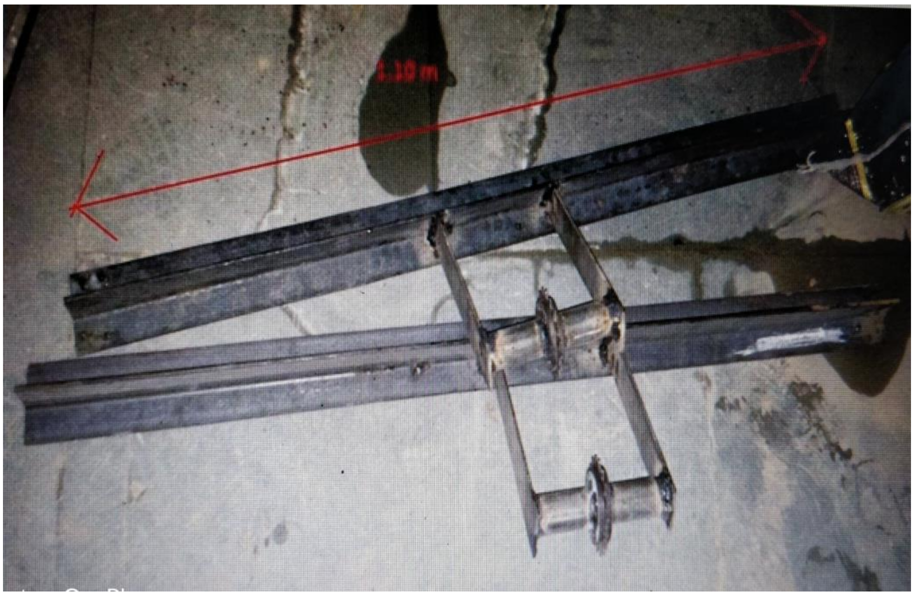


Fig. 3.5 Girder of length 1.10 m{DTU thesis}[4]

Fig. 3.6 Pulley inclined at 45⁰ with vertical and girder fixed on the top of the wall of pit {DTU thesis}[4]

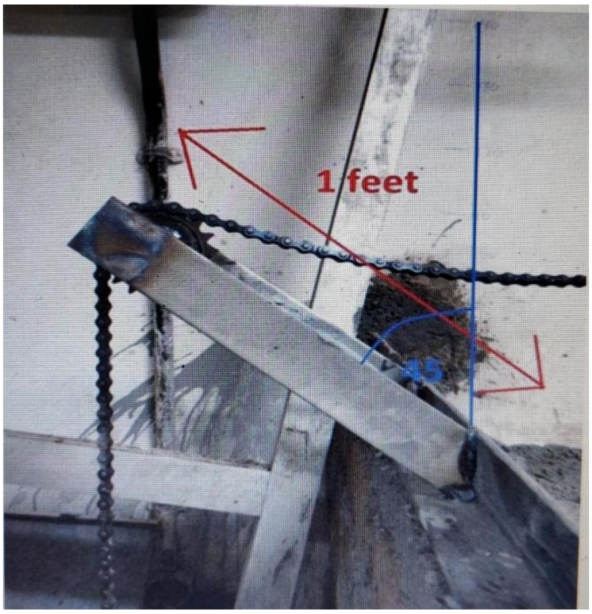


Fig. 3.7 Pulley made an angle of 45° with vertical{DTU thesis}[4]

3.5 **Arrangement to apply Pull out force on pile in axial direction**

Pulleys, High tension bearing wire and weight are use for the pull out of pile. Mechanism was made such a manner that when we hang equal weight both side of the high tension wire, additive pull out force acting on the pile in axial direction.

Fig.3.8 Full set up of Pull out test

When hang load on high tension wire was increase, Pull out force acting on pile was also increase simultaneously.When load increased up to a limit pile suddenly came out from Yamuna sand.

3.6 **Arrangement to apply pure torsional force pile**

Top end of steel pile was welded with two sprockets. Sprockets were welded from up and down with pile and chain was also wrapped around it. Mechanism was made in such a manner that additive torsional force was produced when same forces apply on both the chain. Steel pile was rotated when additive torsional force acting on pile.

Fig3.9: complete view of apparatus.

Chain was in tension when we hanged the load on both opposite sides of the chain. As we increased the load, torque acting on pile was also increase at the same time. When torque was produce by hanging load, pile rotates on its longitudinal axis and angle of twist also come on scale as shown in figure 3.10.

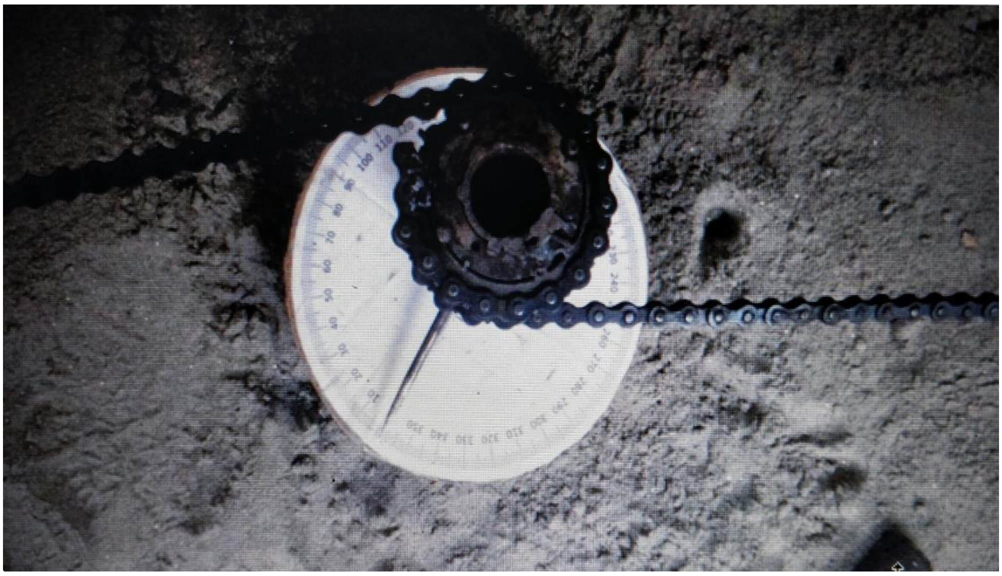


Fig. 3.10 Calculation of angle of twist

3.7 Experimental procedure

3.7.1 For Pull out test

Mechanism was made in such a manner that standard weight loaded with the help of high tension wire and pulley. Photo show the mechanism of pull out of pile. Pull out test was performed on different depth of the pile. Skin friction of pile was calculated at different depth of pile.

Pull out of pile from Yamuna sand at which weight was noted in field book.

Mathematically,
Static Formula Method{nptel.ac.in}[5]

$Q_u = Q_b + Q_s$

$Q_u = q_b \cdot A_b + f \cdot A_s$
$q_b \cdot A_b = 0$

$f = \frac{Q_u}{A_s}$

$f = \frac{Q_u}{\pi . D . L}$

Where,
A_s = Pile surface area(N)
A_b = Area of Pile base(kg)
f = Skin friction resistance by pull out test (N/m^2)
Q_u = Ultimate load bearing capacity of Pile
q_b = Unit bearing capacity
D = Diameter of Pile
L = length of Pile

3.7.2 For Torsion test on Pile

With the help of pulley and high tension chains standard weights was loaded. Mechanism was shown in photos. Experiment was done on loose Yamuna sand. Skin friction of pile was also finding out by torsion method. When we apply the torsion on pile, piles start rotating. At incremental load, angle of twist was also increase. By torsional test on pile we find the skin friction on pile at different depth and different angle of twist.
Mathematically,

$F = m_1 . g + m_2 . g$

$F = f \times \pi \times D \times L$

$$f = \frac{F}{\pi \times D \times L}$$

Where

F = Applied force

m_1 = Mass loaded on first hanger

m_2 = Mass loaded on second hanger

f_o = Skin Friction resistance (N/m^2)

D = External diameter

L = length of Pile

Fig. 3.11 Complete upper view of mechanism producing torque in pile

Fig. 3.12 Elevation view of mechanism producing torque in pile

Chapter 4
Results and discussion

4.1 Sieve analysis

Sieve analysis of Yamuna sand was performed in laboratory and observation sheet was prepared as follows:

S.No.	IS sieve	Mass retained(g)	% Retained	Cumulative % retained	Cumulative % finer(N)
1.	4.75mm	0	0	0.00	100
2.	2.36mm	2.6	0.26	0.26	99.74
3.	1.18mm	4.70	0.47	0.76	99.24
4.	600μ	8.75	0.88	1.67	98.33
5.	300 μ	154.25	15.43	17.64	82.36
6.	150 μ	740.80	74.08	94.34	5.66
7.	75 μ	54.60	5.46	100	0.00

Table 4.1 sieve analysis

4.2 Experimental Study of single Pile for Pull out Test

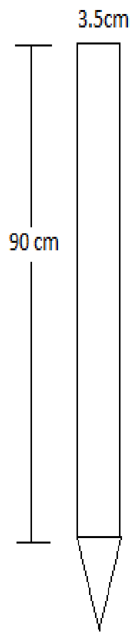


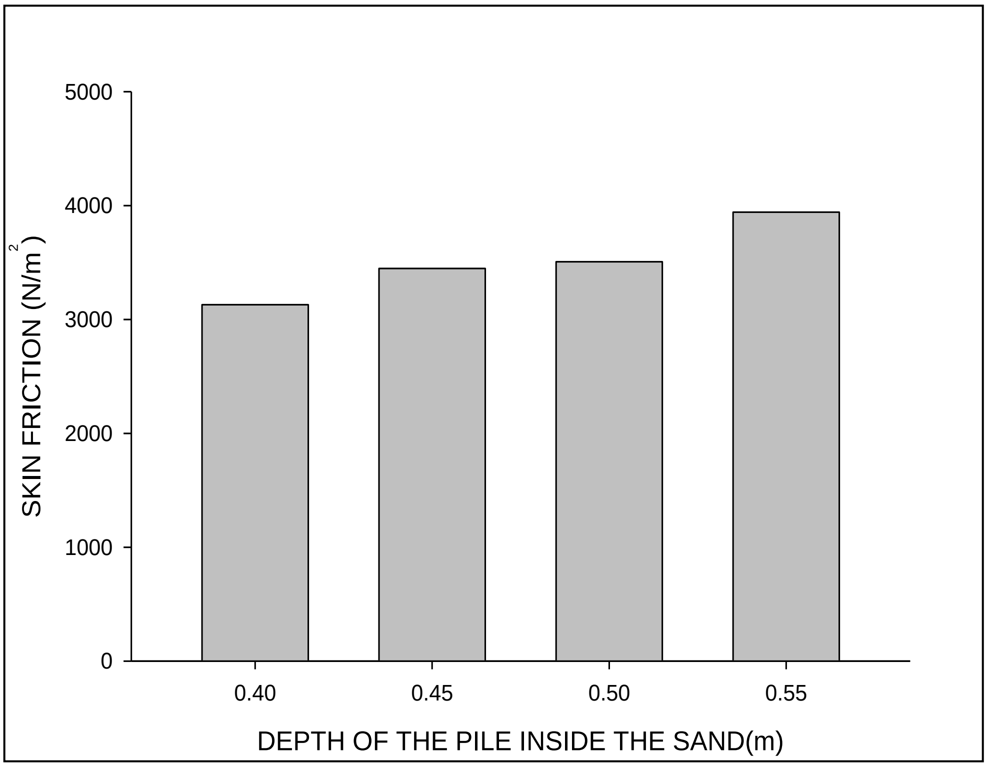
Fig 4.1: Dimensions of steel Pil

1. Pile length = 90cm
2. External Pile diameter = 3.5cm
3. Pile thickness = 3mm
4. Mass of Pile = 6.79kg
5. f = Skin friction resistance by pull out test(N/m^2)

$$f = \frac{Q_u}{A_s} = \frac{Q_u}{\pi . D . L}$$

S.No.	Pile depth inside sand(m)	Pile diameter (m)	Pull out mass (kg)	Pile mass(kg)	Net Pile pull out mass(kg)	Force= mg (N)	Skin friction = f (N/m^2)
1.	0.40	0.035	20.81	6.79	14.02	137.54	3128.75
2.	0.45	0.035	24.17	6.79	17.38	170.50	3447.93
3.	0.50	0.035	26.43	6.79	19.64	192.67	3506.28
4.	0.55	0.035	31.08	6.79	24.29	238.28	3942.42

Table 4.2: Skin friction of Pile for different depth of pile inside Yamuna sand



Graph 4.1: Variation in skin friction of pile at different depth inside sand

4.3 Experimental study of single pile for Torsional Test

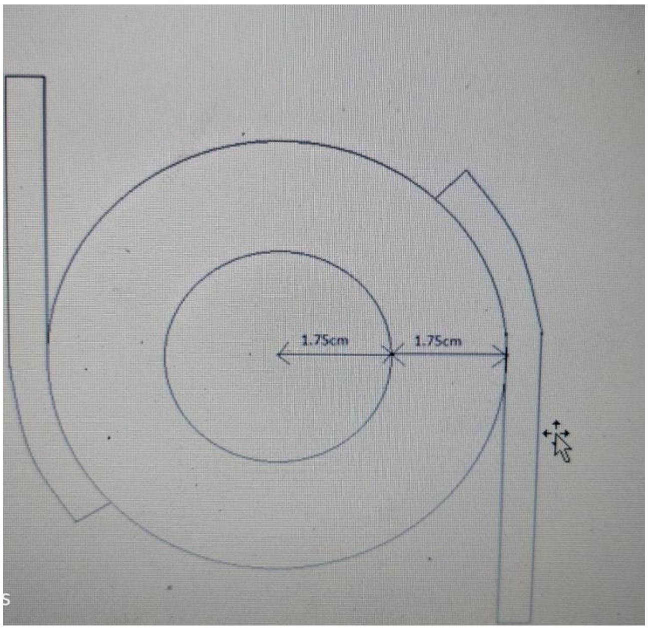


Fig. 4.2 Dimension of pile with sprocket{DTU thesis}[4]

Fig. 4.3 Pile inside the Yamuna sand up to depth 55 cm

1. Pile length = 90cm
2. External pile diameter = 3.5cm
3. Angle of twist = 2^o
4. Pile thickness = 3mm

5. r = length from centre of pile = 3.5cm
6. f_o = skin friction by torsional test(N/m^2)

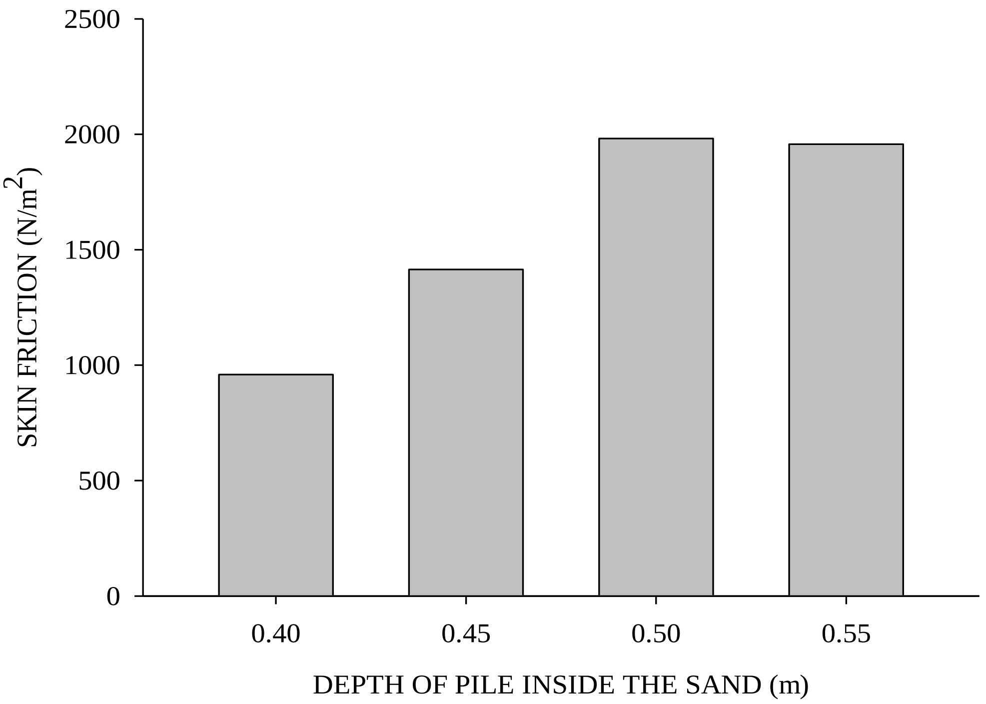
$F = f_o \times \pi \times D \times L$ [$r_{pile} \times f_o \times \pi \times D \times L = 2 \times F \times 3.5$

Whereas r_{pile} =1.75cm

$f_o = \frac{F}{\pi \times D \times L}$ $f_o = \frac{F}{\pi \times D \times L} \times \frac{3.5}{1.75} = \frac{F}{\pi \times D \times L} \times 2$

S.No.	Pile depth inside sand (m)	Angle of twist θ (Degree)	Total mass on both hanger(kg)	Total Force(F)=mg (N)	Skin friction = f_o (N/m^2)	Final skin friction = $2\times f_o$
1.	0.40	2^o	4.30	42.18	959.51	1919.02
2.	0.45	2^o	7.13	69.95	1414.42	2828.84
3.	0.50	2^o	11.1	108.89	1981.62	3963.24
4.	0.55	2^o	12.17	119.39	1975.18	3950.36

Table 4.3: Skin friction of pile at angle of twist 2^o for different depth of pile

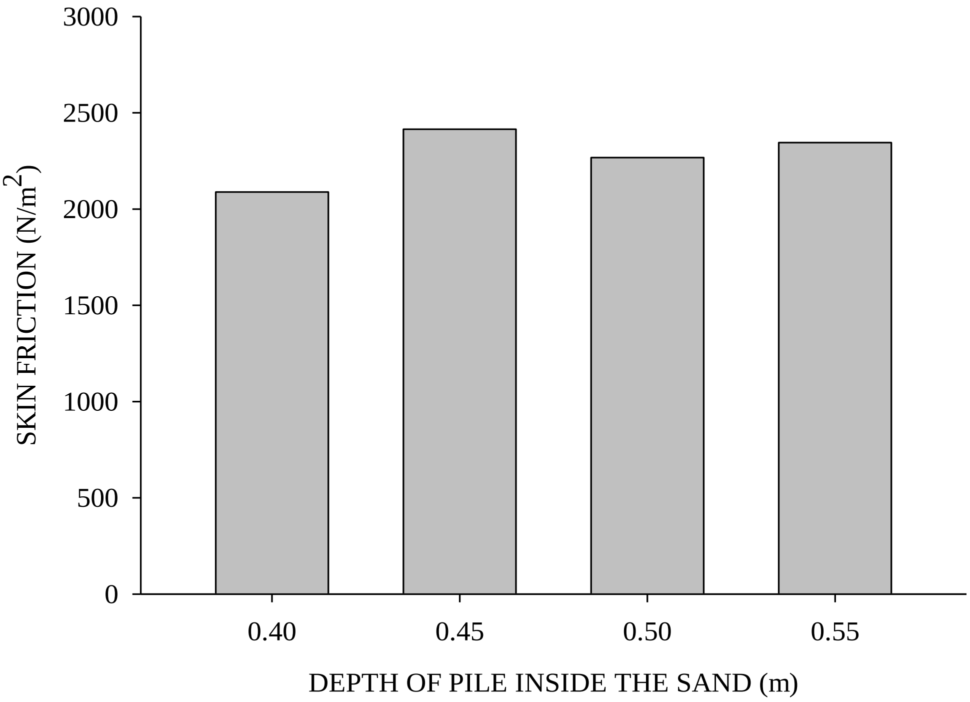


Graph 4.2: Variation in skin friction of pile at angle of twist 2^o for different depth of pile inside sand

1. Pile length = 90cm
2. External pile diameter = 3.5cm
3. Angle of twist = 7°
4. Pile thickness = 3mm
5. r = length from centre of pile = 3.5cm
6. f_o = skin friction by torsional test(N/m^2)

S.No.	Pile depth inside sand (m)	Angle of twist θ (Degree)	Total Mass on hanger(kg)	Total Force(F)=mg (N)	Skin friction = f_o (N/m^2)	Final f_o = $2\times f_o$
1.	0.40	7°	9.36	91.82	2088.72	4177.44
2.	0.45	7°	12.17	119.39	2414.11	4828.22
3.	0.50	7°	12.7	124.59	2267.33	4534.66
4.	0.55	7°	14.45	141.75	2345.11	4690.22

Table 4.4: Skin friction of pile at angle of twist 7° for different depth of pile

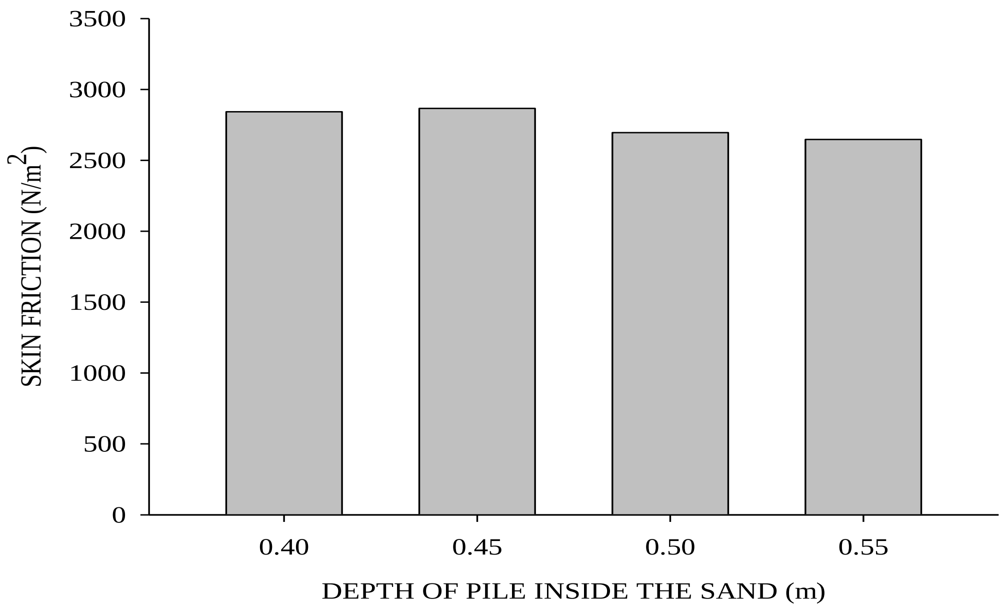


Graph 4.3: Variation in skin friction of pile at angle of twist 7° for different depth of pile inside sand

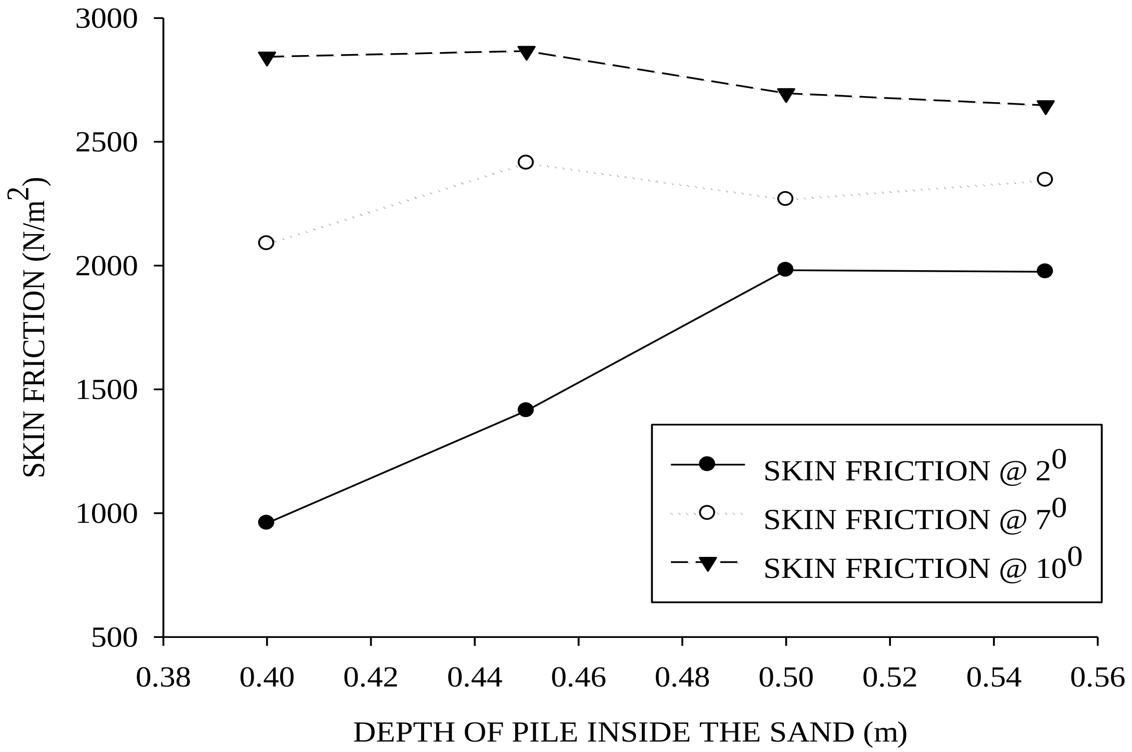
1. Pile length = 90cm
2. External pile diameter = 3.5cm
3. Angle of twist = 10^o
4. Pile thickness = 3mm
5. r = length from centre of pile = 3.5cm
6. f_o = skin friction by torsional test(N/m^2)

S.No.	Pile depth inside sand (m)	Angle of twist θ (Degree)	Total Mass on hanger(kg)	Total Force(F)=mg (N)	Skin friction = f_o (N/m^2)	Final f_o = $2 \times f_o$
1.	0.40	10^o	12.74	124.98	2843.04	5686.08
2.	0.45	10^o	14.45	141.75	2866.24	5732.48
3.	0.50	10^o	15.10	148.13	2695.72	5391.44
4.	0.55	10^o	16.31	160.00	2647.03	5284.06

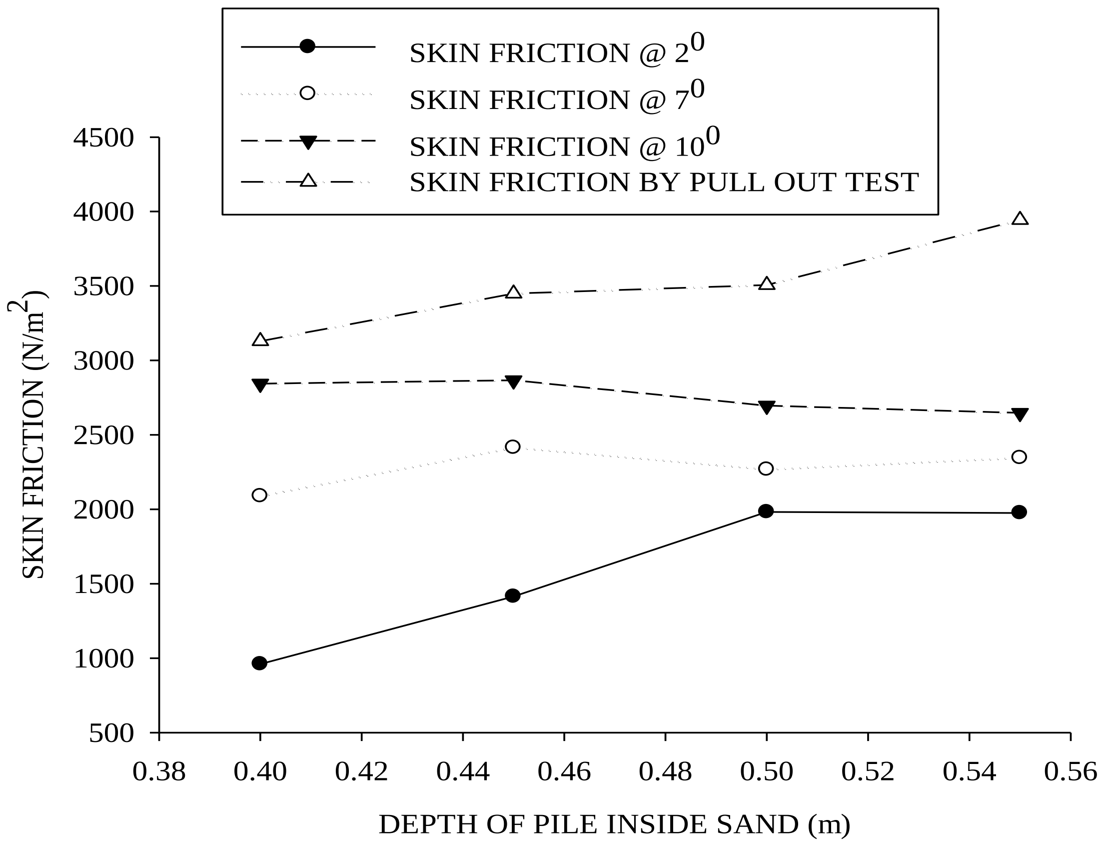
Table 4.5: Skin friction of pile at angle of twist 10^o for different depth of pile



Graph 4.4: Variation in skin friction of pile at angle of twist 10^o for different depth of pile inside sand



Graph 4.5: Variation in skin friction of pile at different angle of twist and depth inside the sand



Graph 4.6: Variation of skin friction of pile by Pull out and Torsional test

- Conclusion of DTU M.tech thesis on “Effect of change of length on skin friction of piles” pile was fail in torsion beyond angle of twist 3^{o}.

Conclusion

1. Skin friction of pile for Pull out test and for Torsional test is in N/m^2.
2. It is investigated that skin friction of pile in Pull out test, increase with increase in depth of pile inside the Yamuna sand.
3. It is also investigated that skin friction of pile in Torsional test, increase with increase in angle of twist.
4. Torsional force is also increase with increase in depth of the pile inside the sand.
5. In torsional test, at largest depth angle of twist is least.
6. Skin friction of pile are affected by several factors such as relative density of sand, method of driven the pile, water content in sand, shape of the pile, surface of the pile and more.
7. Main conclusion of my thesis is skin friction by Pull out test and by Torsional test at 2^o are almost same.

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