



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 6, June 2021

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 7.512**

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)



# Failure in Shallow Foundation- A Case Study

Pratik Sarode<sup>1</sup>, Sameer Wankhede<sup>2</sup>, Sainath Pohorkar<sup>3</sup>, Suraj Dhabale<sup>4</sup>, Rohit Gudadhe<sup>5</sup>,  
Shubham Ade<sup>6</sup>, Dr. Anant Lal Murmu<sup>7</sup>

UG Student, Dept. of Civil Engineering, G H Raison Institute of Engineering and Technology, Nagpur,  
Maharashtra, India<sup>123456</sup>

Assistant Professor, Dept. of Civil Engineering, G H Raison Institute of Engineering and Technology, Nagpur,  
Maharashtra, India<sup>7</sup>

**ABSTRACT-** Excellent building performance during its lifetime cannot be separated from foundation contribution as ground structure that provides stability and support. Foundation intercepts the loads from superstructure and transferring the loads by spreading them over a large enough area to utilize the maximum soil resistance. All loads and forces transferred to the underlying soil will result in some movement, allowable movement. Foundations which experienced movement more than they can resist will cause failure, foundation failure. Distortion and damage from the superstructure was appearing due to the failure. Remedial action will aid the problem and increase the performance of structure to prevent further failure. This research study involves a case of foundation failure. The case is appearing in existing residential building. The study consists of site investigation to determine the site condition, the types and causes of foundation failure, damaged occurred on site and also the types of remedial works carried out. All the types of failure have very strong connection with the soil, because the soil behaviors determine the stability of foundation structure. In the case study, ground settlement is occurred because the soil has low strength stability. The soil contains of clay/silt material which is unsuitable and has low bearing capacity to carry the loads. The ground settlement has produces large and a lot of damages in the residences structure. The remedial work has carried out by underpinning method using combination of micro pile and beam, and also ground stabilization using pressure grouting. From the remedial work that has carried out, it shows there is no more movement in the building. The technique of underpinning has well.

**KEYWORDS-** Shallow Foundation, Residential Building, Underpinning, Grouting, Soil

## I. INTRODUCTION

Cost, time and quality are the main targets for the design and implementation of any foundation. It represents an important part of any building, dam, bridge, tower, etc. The design of foundations of structures requires: the loads that is transmitted by the structure to the foundation, knowledge of the geological conditions in order to understand the type of soil that is present under the foundation e.g. soil nature, soil layers and groundwater depth, the behavior and stress condition of the soil. In addition the standards of the building codes are of importance. It is important to have a good feedback about the project site, because soil nature is heterogeneous. For soil, field investigations and laboratory tests are often required. In addition, information about the geology of the site will be helpful for the designer. Therefore, tests and identifications for soil and rocks must be achieved at each new site before conducting any analysis. Soil is also a foundation for the structure and carries the entire load coming from above. The parameters of soil that must be defined for design purposes are: the grain size distributions, shear strength, plasticity, and compressibility (Bowles, 1996; Das, 2011). For that, design process must start with site investigations to define the types and the mechanical and the chemical properties of the soil. This should be done as all types of soil do not have the same and unique stress-strain relationship. Its behavior is affected by the pressure, time, environment, and many other parameters. The properties found in the soil samples from any location are affected by various factors such as geology of the area, topography, and the methods of soil sampling (disturbed and undisturbed) (Kameswara Rao, 2011; Das, 2011).

Designing and modeling of foundations and structures need two engineering disciplines: the structural engineer to design the structure and the geotechnical engineer to obtain the settlement and bearing capacity of the soil. An overview of the actors and factors must be considered when realizing the structure and foundation. Figure 1.1 illustrates the factors and actors which are involved in modeling foundation structures (Breeveld, 2013).

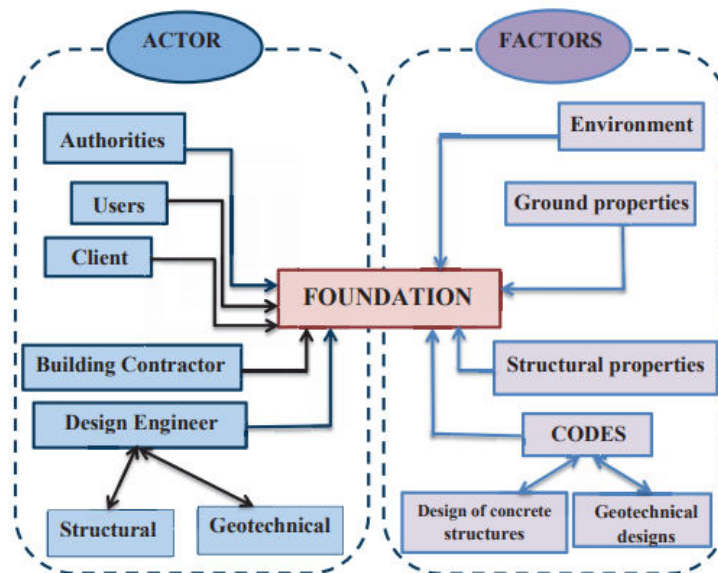


The investigation of a building where a failure has occurred is often necessary to establish the causes of the failure and to obtain the information required for the design of remedial measures. Observations and measurements of the feature of the structure to determine the mode of mechanism of failure are first needed, and these will often suggest the origin of the trouble, or at least indicate whether the ground conditions were partly or wholly responsible.

The main function of foundation is to transfer the loads from superstructure to, the underlying soil or rock over a large area at reduced pressure. It serves as an interface between superstructure and substructure. Generally foundations are classified as shallow foundation and deep foundation. A proper design of foundation system requires the following (i) purpose of engineering structures, possible service life loadings, various forms of framing, soil profile, construction approaches, construction costs, and clients/owner’s needs (ii) design without affecting environment and enough margin of safety with respect to unexpected events and uncertainty in determination of engineering properties of soil and satisfactory tolerable risk level to all the parties, i.e., public at large, the landlord, and the engineer.

Additional contemplations that should be taken into account vary as per particular requirements and purposes, such as, foundation in extreme climate conditions, foundation on loose soils, foundations for different loading conditions like overturning, sliding or uplift, consideration for future expansion, production against corrosion or other injurious material present in soil, suitability with respect to local environment standards etc. It is well understood that engineering structures eventhough being constructed with suitable health and safety measures do fail or collapse.

The failure of a structure may be due to poor design, faulty construction, overloads and foundation failure. The failure of foundation tends to the failure of entire structure, loss of life as well as economical problem. There are several factors contributing to the failure of the foundation, if overlooked or addressed unsuitably, such as, design error, improper soil investigation, fluctuation of ground water table, seismic loads, etc.



(Figure 1. 1: Actors and factors involved in modeling foundations (Breeveld, 2013).)

## II. SITE VISIT DETAILS

Shallow foundation was used in building, normally shallow foundation is the slab-on-grade foundation where the weight of the structure is transferred to the soil through a concrete slab placed at the surface. Slab-on-grade foundations can be reinforced mat slabs, which range from 25 cm to several meters thick, depending on the size of the building, or posttensioned slabs, which are typically at least 20 cm for houses, and thicker for heavier structures. But in this site no foundation failure occurs because hard strata was available and bearing capacity of the soil is high so no foundation failure.



LOCATION:- YASHWANT NAGAR RISHOD ROAD WASHIM DIST WASHIM.  
 OWNER'S NAME:- JAYPRAKAH PAWAR.  
 APPROX ESTIMATE:- 26.20 LAKH.  
 DATE:- 15/3/2021

**III. FOUNDATION FAILURES AND CAUSES**

**3.1 The Types of Foundation Failures**

Shallow foundation failure due to the failure of the soil has discussed in this article. In addition to the soil failure, the foundation could fail due to the failure in a structural capacity. In this article were discussing the foundation that applied a vertical load. Foundation design is done for the allowable bearing capacity. Foundation can reach its ultimate bearing capacity for the ultimate loads applied to form the structure. There are three methods that shallow foundation failure occurs.

**3.1.1 General Shear Failure**

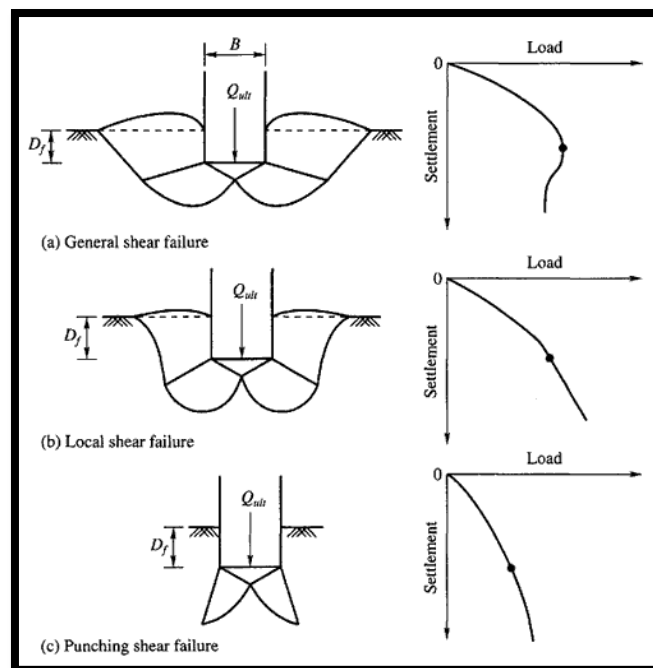
A gradual increase in the load on the foundation will increase the settlement of the footing and increases the pressure under the foundation. When the pressure under the foundation reaches the ultimate pressure that soil can bear, the foundation will fail suddenly. These types of foundation failures occur in low compressible soils.

**3.1.2 Local Shear Failure**

Local shear failures occur in medium compaction soil. An increase in the pressure in the foundation increases the settlement of the foundation and the failure surface in the soil gradually extent outwards from the foundation. Failure surface does not extend to the ground surface as the soil is compressible or due to the deeper depth of the foundation.

**3.1.3 Punching Shear Failure**

This type of shallow foundation failure occurs when the foundation is rested on fairly loose soil where the settlement of the foundation is higher. Shear surfaces are not developed due to the compressibility of soil. The soil under the foundation compressed and it cannot bear the pressure applied from the foundation.



(Fig.3.1 Types of Foundation Failures)



### 3.2 Causes of foundation failure

#### 1. Uneven settlement of soil:

It is the first common causes of foundation failure. In this foundation failure, The cracks are developed in a foundation or buildings due to the Uneven settlement of soil. Due to that, the durability of building is reduced. Also due to cracks, the reinforcement of foundation are corroded.

Causes of uneven of soil:

- Uneven distribution of load
- Change in soil Bearing capacity
- Eccentric loading etc.

#### 2. Uneven settlement of masonry:

The mortar used in masonry is compressed or shrink by applying a heavy load on it before it hard properly due to that, the masonry settles unevenly.

Due to the Uneven settlement of masonry, cracks are developed in foundation which causing failure of the foundation.

#### 3. Sub-soil Moisture movement:

It is the one of the most common causes of foundation failure, which is mainly occur in cohesive soil.

Such a defect occurs where the Water table change it position many times. This fluctuation of ground water causes foundation failure.

If the water table Going down, compresses the soil which causes cracks in the structure. And In the case of water table going rise then the subsoil swell which developed more swelling pressure. In this case foundation have great resistance against swelling pressure otherwise foundation fail.

#### 4. Lateral force applied on a super structure:

The lateral force is applied to the superstructure due to wind, earthquake. If foundation or structure is not designed to resist such forces then the foundation or structure fails due to overturning.

#### 5. Lantern movement of soil:

The soil on sloping land or river bank collapses due to horizontal or inclined force. This type of failure is occurring in soft soil or granular soil.

#### 6. Evaporation by trees and shrubs:

The trees around the construction absorb water from the ground around the foundation so that the structure settles and cracks appear.

#### 7. Atmospheric action:

Heavy rainfall, change in temperature, etc. cause damage to the foundation.

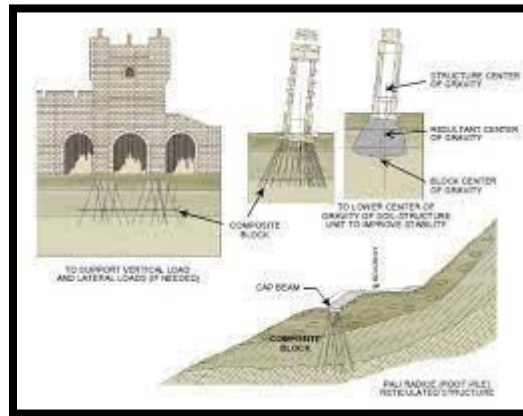
## IV. REMEDIAL WORKS

Based on Site Investigation works result and monitoring program, if performance of building is decreased and the foundations of the buildings must be properly supported (underpinned), whatever the defects and damages observed in the structures need to repaired and patch u.

### 4.1 Underpinning Works

Based on previous site investigation, the building is laid down on 150mm x 150mm square reinforced concrete piles driven down to a maximum depth of 6m and 18m (Ikram SI report, 2006). Because large ground settlement occurred, the stability of foundation has change failed to resist the load pressure due to large movement. During observation, IHSAN consultant has found out that since the ground beams were sitting directly to single pile cap and the brick wall is supported on the ground beam, cracks appears on the wall and this symptom influenced to other structure nearest then the damages start continuing .IHSAN consultants of found out at the pile cap also experienced the cracks because of the movement. Based on study, IHSAN consultant has design and proposed the type of underpinning being used. The combination of cantilever beam and 150mm diameter micro pile with 18m length was used to underpinning the existing single pile cap foundation to overcome the problem (Ihsan Rectification works report, 2007) . Figure below

showed the combination of cantilever beam and micro pile with length 150mm diameter that being used to overcome the foundation failure.



(Fig. 4.1:- Combination of cantilever beam and micro pile)

#### 4.1.1 Sectional View of Underpinning Work

This method is combination between pile foundation and beam, this type of underpinning usually used for low-rise building. This each piles will take greater load once their underpinned. Usually the normal pile is used, depend on loads being carry, and for this pilot test IHSAN consultant has chose micro pile to support the cantilever beam. Micropile sized 150mm diameter was proposed to transfer the load from every pile cap. Explanation below showed the procedures of underpinning process based on Rectification works report.

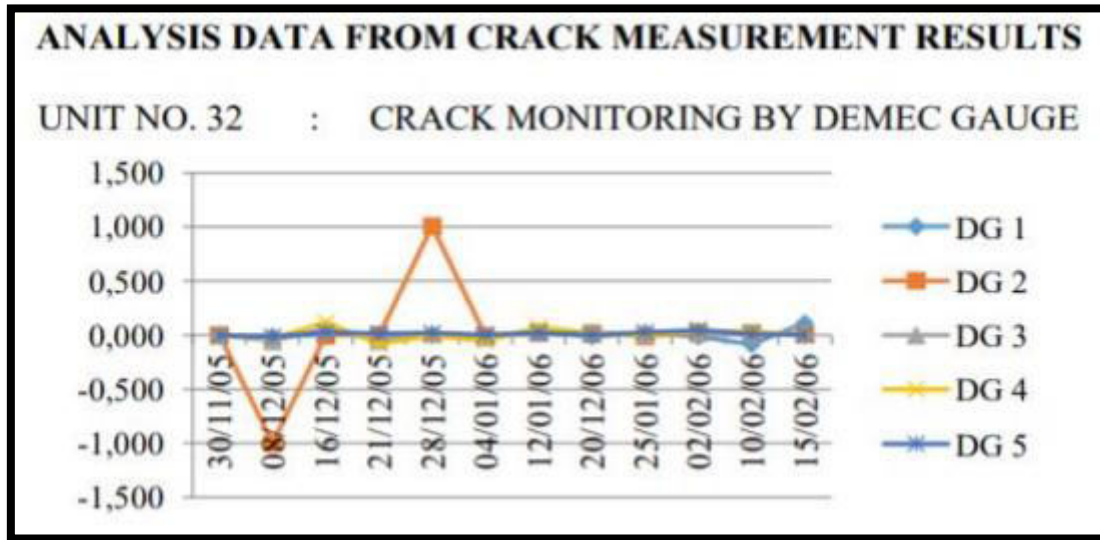
#### 4.1.2 Underpinning Procedures

For pilot test purposes, there are two micro piles was used, compression and tension micro piles, but the compression piles just only driven and drilled into the soil. The depth of drilling process is 18 meter. Figure below is showed boring process for micro piles driven into the soil using micro piles machine. The load from the existing foundation is then transferred into the new pile using a cantilever beam of 230x600mm deep. The bar size is 4Y32 for top and 3Y25 for bottom. With R10-100c/c shear links (Ihsan Rectification work Report, 2007). From report data, there are eight (8) nos. of micro pile can be driven. From the preliminary plans there were twelve (12) nos. of micro pile have been proposed. From the data I have collected; the micro pile is one of efficient structure foundation compare to other type of piles foundation, besides its smaller than other type of pile, it also easy to carry and placed the pile because it usually used small drilling equipment and machine and cheaper than other type of common piles for foundation.

#### 4.1.3 Site Monitoring

The purpose of site monitoring is to verify the cause of damage and determine the rate of movement on the site. IKRAM consultant has divided the monitoring works into; cracks measurement, measurement of soil and building settlement and monitoring of groundwater elevation. Crack and settlement monitoring project is implemented in the house no 32A and no. 36. All the monitoring works was recorded in every week and the length of monitoring period is 3 months. The monitoring works is start from 03 November 2005 until 2 February 2006. Analysis and discussion Demec Gauge can measure very accurately and this equipment is to measuring very small movement. For this crack monitoring Plastic Tell Tale is the equipment to measure, this equipment is very flexible because the reading can be taken without limiting time and no need additional equipment.

The result for this monitoring taken from IKRAM consultant Monitoring Report shows below:- The graph showed the overall result of cracks monitoring in house no.32 using demec gauge. It shows that the crack is quite stable and sometimes there is no movement at all, but from the value of cracks we can see that movement influenced to the opening of the crack in building.



(Fig. 4.2:- Measurement result in unit 32 using demec gauge)

#### 4.1.4 Pressure Grouting

Because of the ground settlement, the ground floor slab become suspended, there are empty space which is have to fill in, this empty space (void) introduce the cracks to the ground floor slab because the floor cannot resist the pressure from upward and the loads also. The void is being confirmed below the slab after site inspection. To fill this void, IHSAN consultant has decided to use pressure grouting to fill the void area under the ground slab. Pressure grouting technique is by injecting the cement slurry to the ground using pump equipment. This method is a common method to stabilize the ground. Pressure grouting has chosen because it's more economical to solve the problem. Base on data collected, pressure grouting also can improve the stability of the ground to support structure above. Pressure grouting was carried out in 29 June 2007 and 4th July 2007 using grade 30 concrete epoxy mortar flow for unit 40 and unit 42. Below is showed the schematic of pressure grouting and diagram of pressure grouting work. The schematic of pressure grouting. All the types of failure have very strong connection with the soil, because the soil behaviors determine the stability of building foundation and the long term performance of the building. The failures of foundation have large impact to the performance of building structure. Distortion and deflection will occur if the foundation is not stable and slightly move. It will create damages to the structure, such as cracks on the wall, beam, and floor and become a problem to the occupants. This problem need to be solve, and remedial work are the option to repair the failure.

#### 4.1.5 Maintenance To Prevent Foundation Failure

Foundation is the supporting link between the building and the ground. They transmit the structure into the ground. But at the same time they transfer any ground movement back to the structure. If the foundation failed to transfer this movement it will effect on distortion and will produce damage to the building structure. This movement related to soil behavior including the bearing capacity of the soil to resist the loads from structure. To prevent the movement take place or minimal to reduce the movement itself, proper maintenance for soil and foundation stability is very important. Below are the methods that can be used to prevent the existing foundation from the failure.

#### 4.2 Types of Remedial Works

Remedial procedures depend upon both environmental factor such as soil behavior and the type of foundation.

##### 4.2.1 Site Investigation

Site Investigation work is very important to collect appropriate information to determine the site condition. From there, the consultant will make the decision and assumption about the work that need to carry out to overcome the failures. The steps of site investigation generally consist of the point stated below.

#### 4.2.2 Testing and Monitoring

Testing and monitoring is very important to identify the accurate ground condition. Site monitoring is divided into 3 (three) categories; Monitoring to establish cause of damage, monitoring to measure rate of movement and monitoring to check success of remedial action.

#### 4.2.3 Shoring

Where a building or structure is in poor condition due to settlement, and underpinning has to be carried out to limit or to arrest resulting movements, external shoring will probably be required. The main shoring members can be of timber, steel or scaffolding. Where timber is used, swelling and shrinking will take place and provision should be made, in the shape of hardwood wedges, to allow for any adjustment which will be required.

#### 4.2.4 Underpinning

Underpinning is the process of modifying an existing foundation system by extending it to or into subsurface strata that are deeper and more stable than the near surface soil that supports the existing foundation system.

### 4.3 Site Investigation Works

#### 4.3.1 Deep Boring test

In this project, IKRAM consultant using Rotary Wash Boring method and Rotary Core Drilling to performed the boreholes. Samples was taking by continues sampling, the initial site investigation that was conducted by KGA Engineering Sdn. Bhd comprised of 6 (six) numbers of boreholes and drilled down to a maximum depth of 30.45m.

#### 4.3.2 Standard Penetration Test

The test performed by follow British Standard 1377 test 19. SPT test was performed to collect the information about bearing capacities of the soil. The samples in the tube (75) mm dropped into bore hole 450 deep using boring rig (63.5 kg), and take the note in each 7.5 cm gap until 45 cm. and the N value determined by the amount of blow for penetration tube sampler from 15 cm to 45 cm. The SPT test was carried out at every 1.0m until 6.0m depth and after that 1.5 m interval to acquire N values. From data report, the number of SPT that have been carried out is about (73) numbers of SPT. The soil that has low bearing capacity and low strength to resist the loads has the chance to settle.

#### 4.3.3 Vane Shear Test

The test is performed based on British Standard test 18. It is suitable for soft soil to solid one or if N value is 2 or less. The procedures is 2 bladed vane with size 6.35cm x 12.7cm inserted into a soil at the foot of a borehole, it is rotated by a rod at the surface with a measure force until the soil is shrink. This in-situ soil test gives shear strength that have been found to give consistent result

### 4.4 Analysis and Discussion

The ground water levels are susceptible to change in the rainy season. Usually the ground water level will increase in the rainy seasons and decrease in the dry season. It useful to monitor and records the groundwater level in longer period because the fluctuations of ground water level maybe the evident. Charts below are taken from the two sets of reading from the standpipes that the ground is seemed to stabilize between 1.38m to 1.78m below the ground level. High ground water level or unstable water table will disturb the characteristic of the soil and reduce the strength of that soil to carry the load, especially when the type of soil is expansive soil. Because this kind of soil is very easy to shrink in dry condition and also expand when in high moisture content.

## V. CONCLUSION

All the types of failure have very strong connection with the soil, because the soil behaviors determine the stability of building foundation and the long terms performance of the building. The failures of foundation have large impact to the performance of building structure. Distortion and deflection will occur if the foundation is not stable and slightly move. It will create damages to the structure, such as cracks on the wall, beam, and floor and become a problem to the occupants. This problem needed to be solved, and remedial work are the option to repair the failure.

The project reviewed discussed the various causes of foundation as well as their possible prevention or remedial measure though case studies. The work is useful for practicing engineer in identifying the potential foundation problem in advance and taking necessary and appropriate action for mitigation purpose.





### ACKNOWLEDGMENTS

The authors are grateful to the G H RAISONI INSTITUTE OF ENGINEERING AND TECHNOLOGY, NAGPUR, MAHARASHTRA, INDIA, for providing guidances and resources to carry out this work.

### REFERENCES

1. Ismael N.F. Allowable pressure from loading tests on Kuwaiti soils. *Can Geotech*
2. Bowles L.E. *Foundation analysis and design*. McGraw-hill, 1996
3. Ornek M., Laman M., Demir A., Prediction of bearing capacity of circular footings on soft clay stabilized with granular soil. *Soils Found* 2012; 52.
4. Lee J, and Salgado R. Estimation of footing settlement in sand. *J Geomech* 2002
5. Omeman Z.M. Load sharing of piled-raft foundations in sand subjected to vertical load.
6. Briaud, J.L. and Gibben, R., Predicted and measured behavior of five spread footings on sand, *Geotechnical Special Publication No. 41*.
7. Buisman, A.S.K., *Grondmechanica*, Waltman, Delft, 190, 1940. 8 Burland, J.B. and Burbidge, M.C., Settlement of foundations on sand and gravel, *Proc. Inst. Civil Eng., Tokyo*, 2, 517, 1984.
8. Burmister, D.M., The theory of stresses and displacements in layered systems and application to the design of airport runways, *Proc. Highway Res. Board*, 23, 126–148, 1943.. Chen, W.F., *Limit Analysis and Soil Plasticity*, Elsevier, Amsterdam, 1975.
9. Ismael, N.F. and Vesic, A.S., Compressibility and bearing capacity, *ASCE J. Geotech. Foundation Eng. Div.* 107(GT12), 1677–1691, 1981.
10. Kulhawy, F.H. and Mayne, P.W., *Manual on Estimating Soil Properties for Foundation Design*, Electric Power Research Institute, EPRI EL-6800, Project 1493-6, Final Report, August, 1990
11. Menard, L., Regle pour le calcul de la force portante et du tassement des fondations en fonction des résultats de pressions métriques, in *Proceedings of the Sixth International Conference on Soil Mechanics and Foundation Engineering*, Vol. 2, Montreal, 1965, 295–299.
12. Meyerhof, G.G., Penetration tests and bearing capacity of cohesionless soils, *ASCE J. Soil Mech. Foundation Div.*, 82(SM1), 1–19, 1956
13. Milovic, D.M., Comparison between the calculated and experimental values of the ultimate bearing capacity, in *Proceedings of the Sixth International Conference on Soil Mechanics and Foundation Engineering*, Vol. 2, Montreal, 142–144, 1965.
14. Vipulkumar C. Patel, Dr. Hemant Thakkar, (2014) “Review on Implementation of 5S in Various Organization”, ISSN : 2248-9622, Vol. 4, Issue 3( Version 1), March 2014
15. Arash Ghodrati, Norzima Zulkifli, (2012) “A Review on 5S Implementation in Industrial and Business Organizations”, ISSN: 2278-487X. Volume 5, Issue 3 (Nov. - Dec.2012).
16. R. S. Agrahari, P.A. Dangle, K.V. Chandratre, (2015), “Implementation Of 5S Methodology In The Small Scale Industry: A Case Study”, *International Journal Of Scientific & Technology Research* Volume 4, Issue 04, April 2015.
17. ASTM D-4546, *Standard Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils*, Annual Book of ASTM Standards, Vol. 04.08., U.S (1996).
18. D. Nagarajan, *Investigation of Foundation failures of residential buildings*, M.E Thesis, Dept. of Civil Engg., Anna university, Chennai, Tamilnadu, India (2013).
19. Richard Driscoll, , *The influence of vegetation on the swelling and shrinking of clay soils*, *Geotechnical research journal*, U.K (1983).
20. Robert W. Day, *Forensic Geotechnical and Foundation Engineering*, (Second Edition, McGraw hill Publications, U.K 2011).



**INNO**  **SPACE**  
SJIF Scientific Journal Impact Factor

**Impact Factor:  
7.512**

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
**INDIA**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details