Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 3; April-June, 2019, pp. 158-163

http://www.krishisanskriti.org/Publication.html

SOIL NAILING BENEATH THE FOOTINGS TO REDUCE SETTLEMENT AND INCREASE THE SHEAR STRENGTH OF COHESIVE SOIL

Musaib Ahmad[1], Er. Charanjeet Singh[2] and Er. Pardeep Singh[3]

[1]*PG Student M. Tech Geotechnicall Engineering, Guru Nanak Dev Engineering College, Ludhiana, India, 7006162026*
[2]*Assistant Professor, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, India*
[3]*Assistant Professor, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, India*
E-mail: musaibahmad73@gmail.com[1]

Abstract—*This research deals with the application of soil nailing technique in vertical form beneath the foundations for improving the weak cohesive soils by reducing the settlements and increasing their shear strength. Clayey soil (CL) was taken for investigation. Geotechnical engineers face different issues amid the installation of foundation on compressible clayey soil because of low shear strength and too much settlement. Hence new and economical techniques are required and looking for creative methods is very important in ground improvement engineering. Keeping these things in mind, the use of the mild steel nails as vertical inclusions beneath the footings for settlement reduction and to increase shear strength of these weak soils is tested in this paper. The provided vertical inclusions with adequate number and anchorage depth can oppose the tensile strains induced due to compressive loads in the sheared zones; therefore, the soil shear strength is enhanced. The nails provided may act as friction pile that shares the load by skin resistance. These nails also provide a kind of confinement which prevents soil from lateral expansion due to applied loads and thus increase the strength of soil. This technique is very different from micro-piles. In this technique the nails were not connected to the footing. This methodology is likewise considered as a less expensive way to be utilized in geotechnical applications, since it requires neither a formwork nor a concrete work.*

Soil sample was subjected to a series of unconfined compression tests with and without vertical nails. The nails were varied in number and lengthwise also. These nails were placed along the periphery of the sample. It was found that when six number of nails were inserted into the sample with sufficient depth, the shear strength got increased by almost 60% of its unreinforced value while the settlement was reduced by 70%.

To take into consideration the scale factor, the soil was again tested under the same conditions but with the size of the sample being comparatively larger. The soil was tested in a cylindrical mould of diameter 300 mm and depth 400 mm with and without nails. The load was applied by the help of manual hydraulic jack. It was found that the shear strength got increased by 70% while the settlement was also reduced by 71% of its unreinforced value.

Keywords: soil nailing, cohesive soil, shear strength, settlement

1. INTRODUCTION

Soil nailing is a sensible and affirmed system utilized in constructing excavations, strengthening slopes and comprehending geotechnical foundations issues by strengthening the ground with moderately little, totally reinforced incorporations, ordinarily steel bars. The behaviour of slants and excavations utilizing the adjustment procedure by soil nailing have been researched utilizing a small scale model and full-scale investigation through contextual investigations in the field or laboratory tests. It is seen from the consequences of these examinations that inclusion of soil nails gives significant changes in soil in the region of nail and improves the shear strength inside the soil mass. Dai et al. (2016) suggested a strategy utilizing Moso bamboo. The bamboo components were utilized as soil nails furthermore, as piles utilizing research facility and field studies. The tests demonstrated that the load limit of bamboo nails is essentially increased by 250% as compared with steel-pipe nails. Then again, a further potential use of soil nails under foundations was demonstrated to control the settlement (Kul, 2003). This method is innovative, new and unique in relation to the micro piles use. In this application, nails were put directly in the soil underneath the footing without connection with footing with distinctive spacings and infiltration depths. The new nail-soil system shares the load together with the foundation. Then again, geotechnical engineers face different issues amid the establishment of the foundations on compressible clayey soil because of lower shear strength and excessive settlements. Consequently, new furthermore, moderate strategies are profoundly required and searching for innovative systems is a critical perspective in ground improvement. In this article, the utilization of the soil nailing system in the vertical form is utilized to improve the shear strength of tested clay samples. This technique is additionally considered as a less expensive way in geotechnical applications, since it does require neither a formwork nor a concrete work. Subsequently, a arrangement of both unconfined compression tests and direct shear tests at different nail/root component lengths and numbers are performed to research the mechanical attributes of such inclusions in the behavior of stabilized clay. The stiffness of the soil nail composite and the failure mechanism is also investigated

The utilization of soil nails is for the most part for slope stabilization. Another potential utilization of soil nail is under footings as settlement reducers (Kul, 2003). This kind of utilization is new and is not quite the same as micro-piles support. Nails are not connected with footings; they are not all that long and vertical settlement of nails is extremely large compared with normal limits experienced for piles or micro-piles. Following the settlement of footing, they share the load together with the footing. The skin friction is for the most part mobilized and end-bearing failure happens constantly happens amid the settlement. The present research manages the evaluation of the soil nailing system with a vertical inclusion to improve the geotechnical parameters of the silty clay soil. A progression of direct shear tests and unconfined compression tests were done to build up the strength attributes of the reinforced silty clay with vertical steel nails.

2. MATERIALS

2.1 Model tank

The steel cylindrical tank was made up of mild steel with diameter 300 mm and depth 400 mm. This tank had a thickness of 3 mm. The size of tank was decided based on available literature. Chumar (1973) suggested maximum extension of influence of failure zone will be 3 times the width of footing below.

2.2 Model Footing

Mild steel footing of diameter 100 mm and thickness 20 mm was used as rigid footing. The footing was placed beneath the jack of the loading test to distribute load coming from above.

2.3 Reinforced element

Commercially available smooth mild steel nails were used as vertical inclusions. This nail has a diameter of 2 mm for UCS test and 6 mm for larger cylindrical mould. These nails are of various lengths viz; $0.25L_o$, $0.50\ L_o$, $0.75\ L_o$ and $0.80\ L_o$. The nail was pressed into the UCS mould which has a diameter of 50 mm and length of 105 mm. The same technique was used while inserting these nails into the larger cylindrical mould.

2.4 Soil

The soil is taken from punjab region whose propertiesl are given below in tabular form

Table 1 Properties of soil

Sp Gr	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Water Content (%)	Bulk Density (kN/m3)	Soil type
2.64	42	25	17	18	18	CL

3. EXPERIMENTAL PROGRAMME

3.1 Unconfined Compression Test

The testing program is done to examine the impact of utilizing vertical steel nails on the UCS of clayey soil. The unconfined pressure test involved in the present investigation is a speedy and successful test that gives a reasonable premise to the examination between various tried parameters. Initially, so as to decide the ideal arrangement range (R) for introducing the strengthened component, a progression of unconfined pressure tests is led at various arrangement radii of R/Ro = 0.25, 0.5, 0.7 and 0.8. The example range is Ro = 50 mm and its tallness is Lo = 105 mm. The test outcomes demonstrate that the ideal arrangement range for the test plan of root components is found at R/Ro = 0.7 because of a higher convergence of stresses at the external edge of the soil sample rather than at the inside zone characterized by low pressure. In this way, in all test arrangement, the arrangement radius is taken as consistent at R = 0.7Ro. The number of components (N) and root/nail height (L) are additionally changed to demonstrate their consequences for the shear strength and settlement of the tested samples**.**

So as to find the UCS of the unreinforced and strengthened examples, a progression of unconfined compression tests at the loading rate of 1.2 mm/min is applied as per IS 2720 part 10. The load is estimated utilizing a calibrated ring with a limit of 5 kN. The vertical strain (ε) and the typical compressive stress (σ) are gotten utilizing the ensuing equations,

$\sigma = P/A$ ………………. (1)

$\varepsilon = L'/L_o$ ………………. (2)

$A = A_o/(1-\varepsilon)$ ………………. (3)

Where,

P= load in kN ,

A= cross-sectional area in mm^2,

A_o = initial cross-sectional area of the sample in mm^2, and

L' = variation in the sample height in mm

3.2 Direct Shear Test

For more illumination, the behavior of silty sand with vertical elements is likewise explored utilizing direct shear test system. It is considered as a legitimate method to research the greatest shear stress in the reinforced sample. The direct shear test is done as per IS 2720 part 10 which portrays the shear strength behavior of the tested sample under draining conditions. Soil samples with or without nail components are tested in 60 mm × 60 mm square shear boxes. The samples are set up in the shear box at the bulk condition and strengthened utilizing the predetermined number of nails components with a depth equivalent to the sample depth (40 mm) as a floating component to keep away from end bearing. The tests are performed under various typical loadings ranging from 50 kPa to 150 kPa and at load rate of 1.2 mm/min

3.3 LOADING UNDER MANUALOPERATING HYDRAULIC JACK

Load settlement tests were also done in larger steel cylindrical tank. The tank had diameter of 300 mm and depth 400 mm with thickness of 3 mm. Soil was placed in the tank in layers and each layer was compacted according to IS light compaction standards. The reinforcing elements were introduced into the soil sample by hammering technique. Loading was applied by hydraulic jack unto allowable settlement limits set by the different IS codes

Table 2 Number of tests done

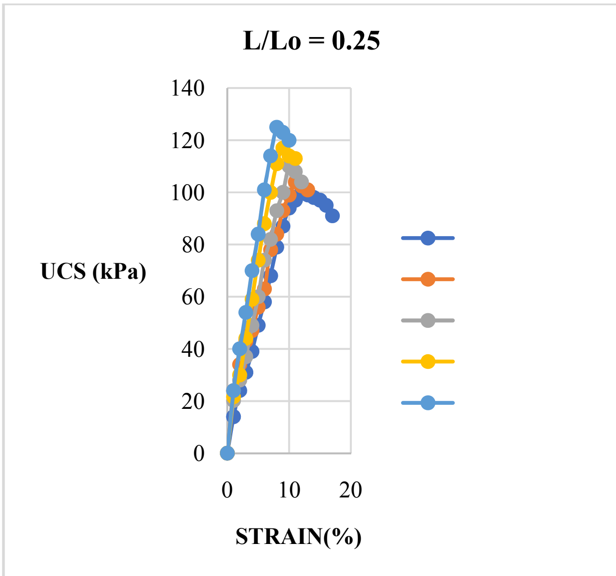
Test	Constant parameters	Variable parameters	Number of tests
DST	N=0	Σ=50,100,150kPa	3
	N=2	Σ=50,100,150kPa	3
	N=4	Σ=50,100,150kPa	3
	N=6	Σ=50,100,150kPa	3
	N=9	Σ=50,100,150kPa	3
UCS	N=0	-	3
	N=2	L/Lo=0.5,1.0,1.5,2.0	4
	N=3	L/Lo=0.5,1.0,1.5,2.0	4
	N=4	L/Lo=0.5,1.0,1.5,2.0	4
	N=6	L/Lo=0.5,1.0,1.5,2.0	4
Load by Jack	N=0	-	3
	N=2	L/D=0.5,1.0,1.5,2.0	4
	N=3	L/D=0.5,1.0,1.5,2.0	4
	N=4	L/D=0.5,1.0,1.5,2.0	4
	N=6	L/D=0.5,1.0,1.5,2.0	4

The above table shows the summary of the various tests performed. In unconfined compression test, the sample height is constant and is 105 mm while diameter of sample is 50 mm so that L/D ratio is 2-2.5. The L/D ratio = 0.5,1.0,1.5 and 2.0 in case of large cylindrical tank, where D is the diameter of the footing. The nail length is kept constant and equal to 40 mm in case of direct shear test.

4. RESULTS AND DISCUSSIONS

4.1SHEAR STRENGTH RESPONSE IN UNCONFINED COMPRESSION TEST

So as to examine the impact of utilizing vertical reinforcements/nails on the clay strength amid the unconfined compression test, load is placed gradually on clay sample with or without nails to foresee the stress– strain response. Fig. demonstrates the stress– strain relationship of silty clay soil strengthened with different numbers of vertical incorporations and at different depths. It is discovered that the vertical incorporations can significantly improve and adjust the stress–strain curves as compared with the unreinforced samples. They can enhance the UCS with decrease in the post peak shear stress particularly for samples with N ≤ 4 and L/Lo = 0.5. It tends to be noticed that a steady increment in resistance from ultimate stress with littler strain is accomplished as the number of nails is increased. In the event of L/Lo = 0.25 and N = 6 as shown in fig, improvement in UCS is observed to be 25% of it unreinforced sample. These improvement rates are observed to be 31%, 45% and 60% at nailing depth ratios L/Lo = 0.5, 0.75 and 0.85, individually. The improvement in the shear strength of the clay samples is because of the strengthened components that are introduced in a highly sheared zone and oppose the prompted tensile strains related with compressive stresses. Also, the side friction between the soil and nails with higher length can appreciably increase the shear strength. Additionally, it very well may be seen that the vertical nails go about as vertical piles that carry the vertical loads with silty clay. Accordingly, the vertical incorporations can relieve both the settlement and the higher strain at failure.



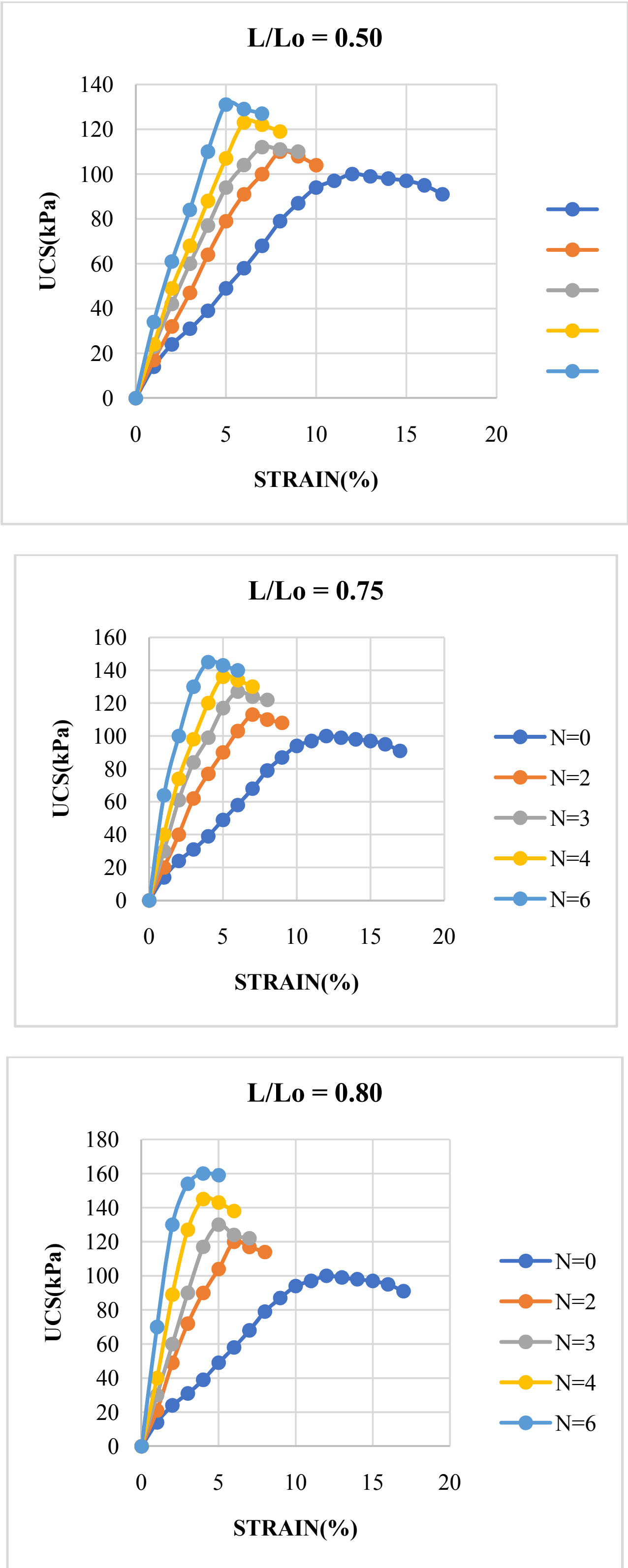


Figure 1 Stress strain curves for clay samples reinforced with different number of nails

It is inferred that the rate of decline in vertical deflection with the increments of both the safe anchorage depth and the number of nails is clearly more noteworthy and goes up in the event of L = 0.85Lo and N = 6. The vertical nails could give the confinement effects to the soil sample test that controls the deformation and builds the clay stiffness. At the point when the samples without nails are compacted, it can distort laterally. The compressed sample in this way attempts to keep running away from the applied loads and move through the zone of least stress with a shortest way. The vertical nails limit the vertical and horizontal distortions of silty clay under various loadings as is clear in figure. This figure shows the adequacy of utilizing vertical nails with different numbers and at different depths to increase the unconfined shear strength of clay. The strengths ratio, characterized as the proportion of the UCS of the strengthened example to that of the unreinforced sample, is found for various cases to demonstrate the level of progress in the UCS. Thus, the UCS is increased. Clearly the UCS is increased to 160%, 145%, 131% and 125% for tests strengthened utilizing six nails with L/Lo = 0.85, 0.75, 0.5 and 0.25, individually, as shown in Fig. 3, while these upgrades in strength proportion are dropped to 120%, 113%, 110% and 104% of its initial value utilizing two nails in a similar manner of consideration depth.

4.2 LOAD SETTLEMENT TEST RESULTS UNDER HAND OPERATING HYDRAULIC JACK IN LARGE CYLINDRICAL TANK

The same pattern (as that in UCS test) of nails was followed in large steel cylindrical tank of comparatively larger dimensions as compared with sample size of unconfined compression test. It was found that there is not much scale affect as the results were very close to that of unconfined compression test. However, a slight increase in the strength of the soil was observed when N = 6 at depth ratio of L/D = 2.0.

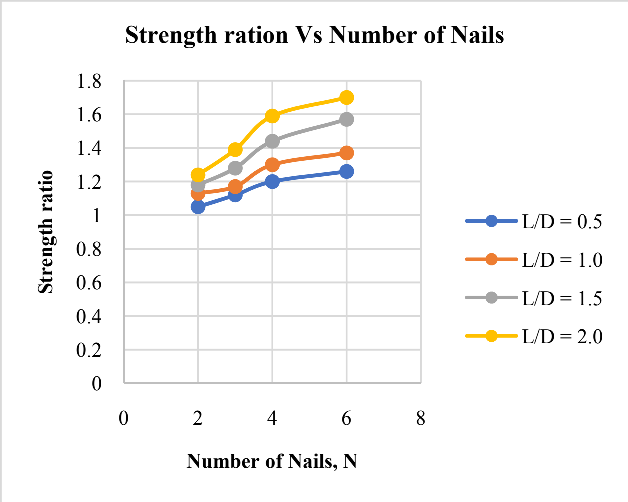


Figure 2 variation of strength ratio against number of nails for clay sample tested in large cylindrical tank with manual hydraulic jack

This slight increase may be attributed to the increase in the contact surface area of the nails and surrounding soil. The strengths ratio, characterized as the proportion of the load of the strengthened example to that of the unreinforced sample, is found for various cases to demonstrate the level of progress in the load bearing capacity.

4.2.1 Reduction in settlement due to nails

The rate of decrease in the settlement of strengthened clay sample can be obtained utilizing the below given equation

$PRS = (S_{rein} - S)/S$, where

PRS = Percentage reduction in settlement

S_{rein} = Settlement of reinforced sample

S= Settlement of unreinforced sample

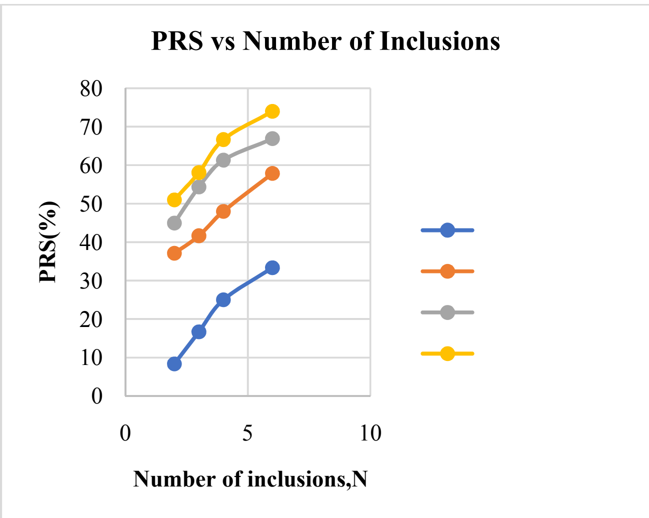


Figure 3 PRS vs Number of nails

In the UCS and hydraulic jack test, by increasing the nail depth, the load is transferred to lower zones of low stress. Subsequently, a noteworthy decrease in the settlement is obtained. The increments in the nail depths and their numbers influence the vertical load to get transferred to the deeper layers of soil underneath the nail toe. What's more, the skin friction along the nail surfaces additionally increment the resistance from distortion and limiting vertical settlement. As appeared in Fig., the varying of of PRS with the nail number for various depth justifies the viability of such components in lessening the settlement of the clay soil. The use of vertical inlusions at sufficient depths (L = 0.85Lo) and with six inclusions adds to a linear connection among PRS and N and diminishes the clay settlement by as much as 70%. The PRS is pointedly diminished when the depth and number of nails are reduced. With the base number of incorporations (N = 2), the settlement decrease is observed to be 8%, 33%, 41% and 50% at consideration profundities of L/Lo = 0.25, 0.5, 0.75 and 0.85, separately. It is clear in light of the fact that the more extended consideration can transmit the loads outside the zones of the greatest pressure, thus reducing the settlement.

5. CONCLUSIONS

1. Appreciable increase in strength (UCS) with littler strain is accomplished as the number of inclusions is increased with depth ≥0.5Lo.
2. Utilizing six nails builds the UCS to 125% and 160% for L/Lo = 0.25 and 0.80, respectively. These values corresponding to large sample tested under hand operated hydraulic jack are 126% and 170%. The little increase may be attributed to the increase in surface contact area between nails and surrounding soil.
3. For N ≤ 4 a partial sample confinement condition is achieved and little improvement in the shear strength of clayey soil is seen
4. The nails provided may act as friction pile that shares the load by skin resistance.
5. The settlement of strengthened soil sample is diminished by 71% when L = 0.80Lo and N = 6.
6. To get the maximum effect in improving the clay stiffness and to totally wipe out the shear failure, the nails ought to be reached out to a deep zone with adequate numbers. Hence, general shear failure of unreinforced test sample can be converted into plastic failure

This technique would be a cheaper one and will not consume too much of time for nailing installation in the ground. Moreover, no kind of concrete work and form work is needed

REFERENCES

1. Alessandro Mandolini(et al.) Rational Design of Piled Raft; 11th International Conference on Modern Building Materials, Structures and Techniques, MBMST 2013,Elseveir
2. Alberto Jaime Miguel P. Romo, Associate Member BEHAVIOR OF FRICTION PILES IN MEXICO CITY CLAY [Journal]. - [s.l.] : Journal of Geotechnical Engineering, 1990. - Vol. 116.
3. Aydogmus Taner Skin Friction between Peat and Silt Soils with Construction Materials [Journal]. - [s.l.] : Electronic Journal of Geotechnical Engineering, 2005
4. Azzam W.R and Basha A Utilization of soil nailing technique to increase shear strength of cohesive soil and reduce settlement [Journal]. - [s.l.] : Journal of Rock Mechanics and Geotechnical Engineering, 2017. - 6 : Vol. 9.
5. Blanchet R., Tavenas F and Garenaves R Behaviour of friction piles in soft sensitive clays [Journal]. - [s.l.] : Canadian Geotechnical Journal, 1980
6. CLANCY P. and RANDOLPH M. F. AN APPROXIMATE ANALYSIS PROCEDURE [Journal]. - Austrailia : INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS, 1993. - Vol. 17
7. Feligha Marwa [et al.] Experimental Investigation of Frictional Behavior Between Cohesive Soils and Solid Materials Using Direct Shear Apparatus [Journal]. - [s.l.] : Geotechnical and Geological Engineering, 2016. - 2.
8. Filz George, F. ASCE P.E and Sloan Joel Column-Supported Embankments: Settlement and Load Transfer [Journal] // geotechnical engineering . - 2012. - p.10
9. Fioravante Vincenzo and Giretti Daniela Contact versus noncontact piled raft foundations [Journal]. - [s.l.] : Canadian Geotechnical Journal, 2010.
10. Hung-Jiun Liao;Shi Fon Su Ground improvement piles induced shear strength increase in normally [Journal]. - [s.l.] : Journal of the Chinese Institute of Engineers, 2006. - 1 : Vol. 29