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EFFECT OF SAND AND GEOGRID REINFORCEMENT ON BEARING CAPACITY OF SAND ADMIXED POND ASH

UTICAJ DODATKA PESKA I GEOREŠETKASTOG OJAČANJA NA KAPACITET NOSIVOSTI MEŠAVINE PESKA I PEPELA SA ŠLJAKOM

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Ključne reči
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Abstract

To dispose of the waste materials is one of massive problem all over the world as it requires a vast area, as large quantities of pond ash are being generated from thermal power plants which gives rise to disposal problems. Also, it constitutes fine particles of fly ash that create health problems and is also considered as environmental hazard. To enervate these engineering problems, it can be used as construction material in various construction projects and can further be used as filling material in low lying areas. The current study works upon evaluation of bearing capacity by replacing the pond ash with sand in optimum proportion. Further, the mix deposit is reinforced with geogrid reinforcement at suitable depth below the base of footing and its effect on strength of deposit is evaluated. The results revealed that with addition of 15 % optimum sand content in pond ash, the maximum dry density of the mix increases, and optimum moisture content gets reduced and further can be used for the enhancement of bearing capacity of pond ash bed. During the failure mechanism in laboratory plate load test, the bed was bulged on both sides of tank. Further, the study was carried out in laboratory setup to evaluate the effect of reinforcement on the strength of pond ash bed alone and sand admixed pond ash. For single layer of geogrid layer reinforcement the optimum depth was observed as 0.5B.

Izvod

Odlaganje otpadnog materijala je jedan od najvećih problema u svetu jer zahteva ogroman prostor, a ogromne količine pepela i šljake nastaju u termoelektranama, čime se ti problemi samo uvećavaju. Otpadni materijal čine fine čestice letećeg elektrostatičkog pepela, koji izaziva zdravstvene probleme, a takođe je ekološki štetan. Za rešavanje ovih inženjerskih problema, može se upotrebiti kao konstrukcioni materijal u mnogim konstrukcijama, a može se upotrebiti i za nasipanje slojeva u nižim predelima. U radu se istražuje procena kapaciteta nosivosti mešavine pepela i šljake i optimalnog udela peska. Dalje se mešavina ojačava georešetkom na odgovarajućoj dubini ispod temeljne stope i zatim se procenjuje uticaj na čvrstoću. Rezultati pokazuju da sa dodatkom 15 % optimalnog sastava peska u pepelu i šljaci, dolazi do porasta maksimalne gustine suve mase, a optimalan sadržaj vlage se smanjuje i dalje se može upotrebiti za povećanje kapaciteta nosivosti podloge od pepela i šljake. U laboratorijskom ispitivanju opterećenja ploče mehanizam loma je okarakterisan izbočavanjem obe strane posude. Istraživanja su izvedena u laboratoriji radi procene uticaja ojačanja na čvrstoću podloge pepela i šljake, kao i sa dodatkom peska. U slučaju jednostrukog ojačanog georešetkastog sloja, zabeležena je optimalna dubina od 0,5B.

INTRODUCTION

Pond Ash is the byproduct resulting from thermal power plants which is waste and is precarious from the environmental point of view. According to the report published by Central Electricity Authority in the year 2016-2017, thermal power plants generated 175 million tons of fly ash annually. Normally two types of coal ash are being generated, i.e., bottom ash and fly ash. Afterwards, these are mixed together to get transported in ash pond and residue and such remains at the bottom with coarser nature are known as *pond ash*. To dispose of such a large quantity of pond ash, an immense area is required being the problem as in the present scenario. So it is preferred to use it in various fields of civil engineering projects as construction material which is otherwise a waste material. In earlier time, pond ash was being used to fill the low lying area but in the present requirement it can be used as construction material so that the overall project cost can be optimised. It is troublesome to use pond ash in foundation and road construction due to the low bearing capacity and poor shear strength. So it is advisable to provide reinforcement so that the overall strength of the pond ash gets enhanced. Various geo-textile materials can be used to enhance the overall strength of the pond ash. Geo-grid may be used to strengthen the load carrying capacity of the pond ash. For the past few years, the matter of strengthened soil beneath the foundation has gained much attention from the research point of view.

Literature review

An enhancement in the bearing capacity of square footing (resting on pond ash) was noted when reinforced with geotextiles /7/. The effect of geogrid layers reinforcement was observed on the bearing capacity and settlement ratio of square footing resting on fly ash slope /3/. The enhancement in bearing capacity and settlement ratio was observed in strip footing (resting on granular soil) when strengthened with geogrid layers /13/. Approximate increment around 138 % in bearing capacity of square footing reinforced with geocell was observed when rested on well graded sand, /5/. The various strength parameters like strength of footing, UCS and CBR of soft soil gets improved when it is admixed with fly ash. For large settlement values, the bearing capacity of subgrade soil gets enhanced when reinforced with geocell /14/. The qualitative and analytical studies were carried out on rigid footing (resting on sand slopes) reinforced with geogrid and geogrid anchor. The effect of both reinforcements was studied on the bearing capacity of the material and comparison was made for both materials, /2/. An enhancement in bearing strength of circular plate (laid on coarse soil) up to 7.5 times was observed when strengthened with hollow cylinder (diameter equals to footing diameter) beneath by geogrid layer, /6/. The stiffness and bearing capacity of strip footing was enhanced when geogrid layer was placed at bottom layer of geocell reinforced soil, /4/. The study was carried out on plastic soil admixed with bottom ash and found the increment in CBR value (up to 24 %) and bearing capacity, /16/. The laboratory plate load tests were conducted to study the effect of waste tire mat on the bearing capacity and settlement ratio and was concluded that settlement ratio gets reduced (up to 70 %) with consequently an increment in gross strength of the footing, /13/. Corresponding to optimum depth of 0.5 times of footing width, the jute geotextile was found effective to enhance the load carrying capacity by 3.5 times of the original value /9/. The CBR test was performed to study the strength of sub grade soil and found the increment in the strength by reinforcing with geosynthetics, and less impact was seen on strength when reinforced with Texas 3-D reinforcement, /10/. An experimental investigation was carried on sandy soil to study the effect of reinforcement layers spacing and angle of internal friction on bearing capacity of soil /12/. The testing was carried out on strip footing resting on soil setup consisting of unreinforced and randomly distributed fibre-reinforced pond ash (RDFP) lying over soft soil and was concluded that bearing capacity gets improved corresponding to 1.5B thickness of fibre and was optimum corresponding to 1 % fibre content in the mix. The laboratory plate load tests were conducted on sand admixed pond ash reinforced with natural fibre and concluded that the load carrying capacity enhanced by reinforcing it with natural fibre /18/. An experimental and numerical study was conducted on embedded footing overlaid on dense sand slopes for both unreinforced and geotextile reinforced cases and found that the strength gets enhanced with the increase in embankment and edge distance, /10/. The experimental testing was conducted on circular base footing laid on sand to study the effect of reinforcement layers geocell on underground pipelines and found that surface settlement was reduced to 68 % and total settlement to 38 %, as compared to unreinforced soil /11/. A detailed numerical procedure of strip foundation laid on sand bed embedded with geotextile strip layers to enhance bearing strength of footing was carried out and was found that there was significant increment in load bearing strength, /20/. An experimental study was conducted to study the effect of geocell made up of three different materials on the load bearing strength of strip foundation laid on coarse soil mattress and was concluded that reinforcement leads to reduction in surface heave and bearing capacity ratio was found nearby to 8, /4/. The study was carried out using Plaxis 3-D software to study the effect of geotextile reinforcement on two close strip footing resting on soft clay and was found that bearing capacity increased with increase in number of reinforcement layers if they were installed at effective depth within the soil, /23/. The laboratory testing was executed on sand bed to analyse the effect of 3-D arrangement of geotextile reinforcement layers on load carrying capacity and concluded that by increasing the reinforcement layers in soil, consequently its load carrying capacity per unit width decreases, /24/. A parametric study using Plaxis 3-D was conducted on shallow footing resting on pond ash deposit with or without reinforcement by varying the length as well as width of geotextile fibre and was noticed that optimum hike in bearing strength was corresponding to the effective depth of reinforcement equal to 2.67B. Moreover, there was increment in load carrying capacity with increase in reinforcement layer and optimum provision of layers was found equal to 2, /25/. The software analysis was carried out on shallow footing laid on coarse grained soil embedded with geogrid layer under off-centre and inclined load using PLAXIS 3D software. Various structures have been analysed for their integrity and life by researchers. The findings have been used in this paper in the discussions, /21, 22/.

The authors analysed two parameters - bearing capacity ratio (BCR) and reduction factor - in small-scale model experiments conducted in the laboratory to determine the efficacy of geogrid-reinforced granular fill overlay on soft subgrade soil. The test findings show that the addition of geogrid to the granular fill overlay over soft subgrade soil significantly improves bearing capacity and decreases footing settlement, /15/. The primary goal of the study is to examine the effectiveness of rubber-soil mixes and geocell reinforcement in strain reduction for buried flexible service pipes and prevent backfill from collapsing under repeated loading events. By covering the pipe with a geocell and adding 5 % of shredded rubber-soil mixture, the minimal soil surface settlement and vertical diametral strain are achieved. Values were 0.30 and 0.53 times lower than those found in the untreated and unreinforced soil, /17/. Under eccentric and oblique loads in both dimensions, the behaviour of a shallow rectangular foundation built over numerous layers of geogrid reinforced sand was investigated. The findings show that when the axial eccentricity and inclination of applied loads rises, the value of the model foundation's Ultimate Bearing Capacity (UBC) decreases. Findings show that bearing capacity of the footing reduces after having the increment in the values of axial eccentricity and inclination with applied load, /19/.

From above literature, it is proved that geotextiles can be advantageously used as reinforcing material to strengthen soil deposit. Less literature has been found on the study of shear strength parameters and compaction characteristics of sand admixed pond ash. Moreover, in current study geogrid is used as reinforcing material to strengthen pond ash and sand admixed pond ash bed. Further, in the current experimental study various factors as number of reinforcement layers, depth of reinforcement below base of footing and overburden pressure were investigated to study their effect on bearing strength of pond ash and sand admixed pond ash bed.

Objectives of study

To find the engineering properties of pond ash mixed with different proportion of sand content; to find optimal content of sand corresponding to maximal dry density of the mix deposit; to study the effect of jute geo-textile reinforcement on the bearing capacity of pond ash mix; to conclude the effect of number of reinforcing layers and soil cap thickness on the load carrying capacity of the pond ash mix.

MATERIALS USED

Experiments are carried out using the materials such as pond ash, sand, sand admixed pond ash and geogrid layers reinforcement.

Pond ash

Pond ash in the present study has been collected from Guru Gobind Singh Super Thermal Power Plant, Ghanauli, Punjab (India). The pond ash was placed near by a laboratory at a dry place to avoid moisture content loss within the material. The pond ash exhibits the property of higher optimal moisture content and some part of the cohesion because of fly ash and silt content within the sample. The physical and chemical properties of pond ash are listed in Tables 1 and 2.

Table 1. Sieve analysis, compaction characteristics and shear characterization of pond ash.

Properties of pond ash	Values
Sieve Analysis values	gravel percent. = 0.9 %
	sand percent. t = 72.1 %
	silt percent. = 27 %
	Cu = 2.9
	Cc = 1.06
	fineness modulus = 2.2
G (specific gravity value)	2.31
LL (liquid limit) and PL (plastic limit)	non plastic in nature
OMC value at Standard Proctor Test	40.1 %
MDD value at Standard Proctor Test	10.1 kN/m^3
Cohesion value (using Direct Shear Test)	28 kN/m^2
Angle of internal friction (ϕ) value (using Direct Shear Test)	270

Table 2. Molecular characterization.

Chemical constituents	Weight percentage in sample
SiO_2	52.5
Al_2O_3	25.5
CaO	0.85
loss on ignition	9.90
MgO	4.1
Fe_2O_3	8.2
others	1.25

Sand

Sand used in the present study is acquired from locally available river site from Ludhiana, Punjab (India), Table 3 . The soil is characterised as poorly graded soil (SP) according to the USCS (Unified Soil Classification system).

Table 3. Sieve analysis, compaction characteristics and shear characterization of sand.

Physical properties	Values of physical properties
Sieve analysis	sand percentage = 83%
	silt percentage = 17%
	Cu = 2.36
	Cc = 1.18
	fineness modulus = 2.90
G (specific gravity value)	2.72
OMC value at Standard Proctor Test	9.2 %
MDD value at Standard Proctor Test	17.9 kN/m^3
Cohesion value (using Direct Shear Test)	3.3 kN/m^2
Angle of internal friction (ϕ) value (using Direct Shear Test)	300

Geogrid

In the present study, polypropylene geogrid bought from M/S strata Geosystem Pvt. Limited (India) is used. Uniaxial geogrid (SGi-040) is used as reinforcing material. The geogrid mesh used in the study is rectangular in shape and numbers of reinforcing layers were varied from 1 to 3 by keeping suitable spacing within the deposit. The reinforcement material taken in the current study is shown in Fig. 1 and properties are listed in Table 4.

Table 4. Physical characterization.

S.No.	Parameters	Value
1 Physical characterization		
	Size of mat used (mm)	230*600
	Perforation size (mm)	60 (MD)*23 (CMD)
2 Uniaxial geogrid mat (single rib tensile strength)		
	CMD value (cross-machine direction)	33.7 kN/m
	MD value (Machine direction)	43.8 kN/m

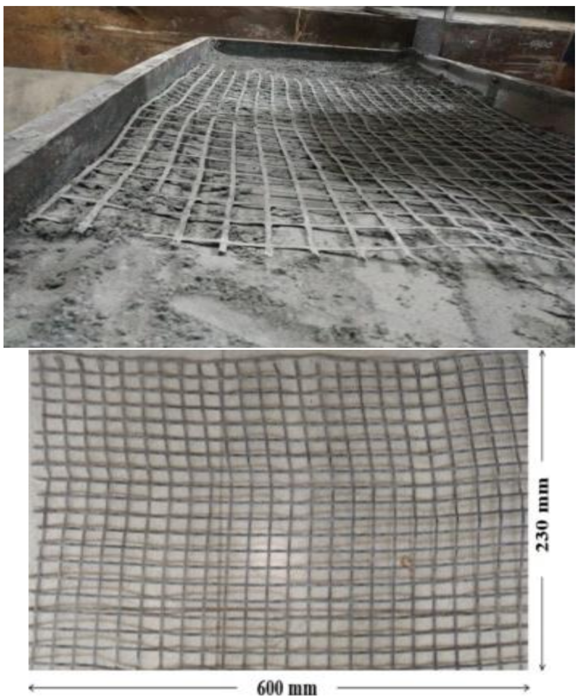
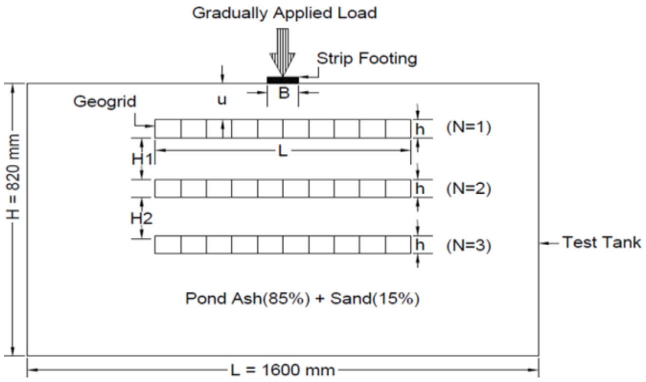


Figure 1. Geogrid mat.

METHODOLOGY

The model strip footing having the dimensions 600 × 100 × 20 mm was placed at the centre of the testing tank. A layer of sand using epoxy was used to make the bottom face of the footing rough. Tank dimensions play a crucial role to find the bearing capacity of strip footing and should be kept around four times the width of footing to diminish the boundary effect /1, 8/. By keeping this factor in consideration, the model tank dimensions were taken as 1600×620×820 mm to reduce the unfavourable effect of boundary conditions. As the tank was rectangular in shape, so three sides of the tank were made of steel and one side of Perspex sheet (6 mm thick) in order to visualize the settlement behaviour of footing. The strip footing was kept top centre of the tank by keeping the length of footing and width of tank in parallel to each other as shown in Fig. 2.



Sr. No.	Variab. used	Description of variables
1	B	width of footing
2	u	depth of first geogrid layer from the base of footing
3	H1	depth of second geogrid layer from the bottom of first layer
4	H2	depth of third geogrid layer from the bottom of second layer
5	N	number of layers
6	h	height of geogrid layer
7	H	depth of tank

Figure 2. Line diagram indicating experimental setup in laboratory and variables description.

Figure 3. Load application in laboratory plate load test.

In order to eradicate side friction effect on model footing, all four sides of the model tank were lubricated with oil. The sides of footing were also lubricated in order to minimize the effect of end friction on test result values. The load was applied on the strip footing through hydraulic jack which further was supported through reaction frame as shown in the arrangement (Fig. 3). The reaction frame was connected to both sides of the tank through nuts and bolts in order to restrict the uplift in the whole arrangement during the loading mechanism. The hydraulic jack was connected to load cell (capacity 35 tonnes) as shown in Fig. 3. This was further linked to a load indicator, therefore the value of applied load was inferred. The schematic diagram of the whole setup assembly is depicted in Fig. 2.

Sample preparation

The testing was carried out on pond ash admixed sand by mixing the sand in optimum proportion as concluded from compaction test results (Fig. 4). The test tank was loaded in layers by keeping the thickness of each layer 15 cm and providing the required compaction effort to each layer with the help of rammer as shown in Fig. 5. To check the desired density in the test tank, the sample was collected in hollow cylinder corresponding to 15 cm bed thickness, placed at 6 different locations in the tank as shown in Fig. 6. The value of density corresponding to 6 samples collected during the trail was found so that the variation was limited to 1 % to the required value ensuring proper compaction. After levelling the bed properly, the strip footing plate was laid on bed

Table 5. Number of samples tested.

S. No.	Material taken as foundation bed	No. of tests performed	Variables
1.	Pond Ash	1	-
2.	Sand admixed pond ash	1	-
3.	Pond ash strengthen with single layer of reinforcement (N=1)	5	u values = 0.1B, 0.3B, 0.5B, 0.7B, 0.9B
4.	Pond ash strengthen with 2 layers of reinforcement (N=2)	3	H1 values = 0B, 0.2B, 0.4B
5.	Pond ash strengthen with 3 layers of reinforcement (N=3)	4	H2 values = 0B, 0.2B, 0.4B, 0.6B

Figure 4. Sample preparation of sand admixed pond ash.

Figure 5. Compaction of sample in test tank.

and the load was applied gradually with the help of hydraulic jack. The settlement behaviour was noted down by dial gauge reading placed on either side of footing. Load was applied on the footing till failure or up to settlement value of 40 mm, which ever was earlier. The different settlement pattern of footing on application load is shown in Fig. 7. Details of tests conducted in the present study are presented in Table 5.

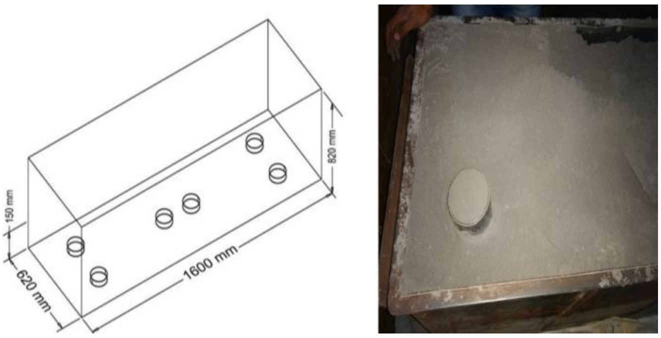


Figure 6. Collection of samples in tank for density check.

Figure 7. Failure of footing during load application.

RESULTS AND DISCUSSION

Compaction characteristics results

Pond ash was replaced with sand likewise in the proportion of 10 %, 15 %, and 20 %, and standard proctor test was conducted to investigate the effect on maximum dry density and optimum moisture content as shown in Fig. 8. It was seen that corresponding to 10 % replacement of sand, the MDD increased from 10 to 11.2 kN/m^3 and no change was observed in OMC as remained same 40 %. On surging the sand content to 15 %, MDD further increased to 11.5 kN/m^3 and OMC value reduced to 35 %. On further increasing the sand content to 20 %, the MDD as well as OMC both have shown a decreasing trend as 10.5 kN/m^3 and 32 %, in respect. The results of compaction characteristics depicted that the 15 % sand content may be taken as optimal content as replacement in pond ash. This may be due to the reason that the sand particle of higher specific gravity increases the MDD by increasing the bulk weight of composite sample up to 15 % sand content and thereafter by increasing the sand content beyond 15 %, the binding forces within particles are not predominant, and thus lowering of the MDD value.

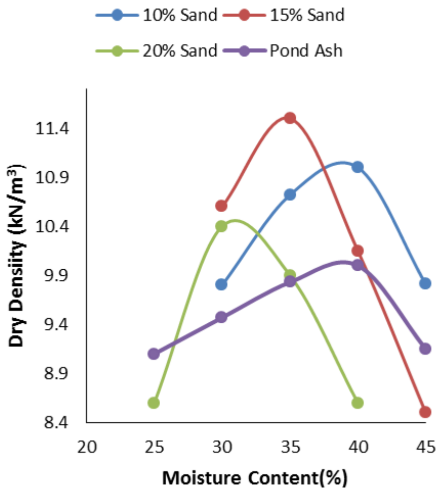


Figure 8. Compaction characterization of pond ash mixed with sand.

Effect on bearing capacity

The bearing strength of strip footing was calculated from different load-settlement curves corresponding to different combinations. Then bearing capacity was calculated by using analytical formula, i.e., load divided by area.

Effect of addition of sand on foundation bed strength

The effect of sand replacement on the bearing strength of the pond ash bed was studied for optimal content of sand, i.e., 15 % (observed from compaction test results) was added in pond ash. The load carrying capacity of the pond ash was 190 kN/m^2 as calculated from load settlement curve shown in Fig. 9. On adding the optimal content of sand in pond ash, the ultimate failure load increased, revealing the enhancement in bearing strength of sand admixed pond ash.

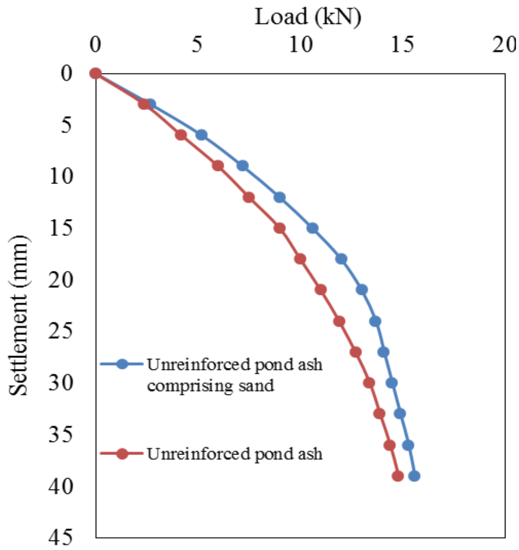


Figure 9. Load v/s Settlement curve for pond ash and sand admixed pond ash.

The load bearing strength of sand admixed pond ash was found to be 215 kN/m^2 which shows an increment of about 15 % as compared to the value of pond ash bed alone. This enhancement in bearing capacity may be due to progressive increase in the angle of internal friction on preparing sample of sand admixed pond ash. Further, the formation of heave on either side of footing was observed as shown in Fig. 7.

Effect of geogrid reinforcement

To investigate the effect the geogrid reinforcement on pond ash bed consisting of sand, 3 layers of geogrid reinforcement were used at suitable spacing below the base of the footing and the load was applied on the setup and consequently settlements were noted down in each case.

Case 1, when N = 1

Figure 10 describes the load settlement behaviour of pond ash bed admixed with sand reinforced with single geogrid layer at various spacing values below the base of footing. The relationship reveals that load carrying capacity increased for all spacing values when reinforced with geogrid reinforcement. Further, the graphs revealed that load carrying capacity increased by increasing the spacing of geogrid reinforcement up to u/B = 0.5. On further increasing the spacing from 0.5 to 0.7, and u/B = 0.9, load settlement curves show the falling down trend, revealing the u/B = 0.7 may be taken as optimal depth as single layer of geogrid reinforcement in pond ash and sand admixture. The load carrying capacity of pond ash admixed sand reinforced with geogrid at u/B = 0.1, 0.3, 0.5, 0.7, and 0.9 was 281, 286.6, 325, 295, and 205 kN/m^2, respectively. The geogrid placed at depth u/B = 0.5 was taken as optimal depth for single geogrid layer as maximum percentage increase in load carrying capacity was observed as 51.6 %. This may be due to the reason that geogrid reinforcement below the base of footing intercepts the failure plane and consequently results in increment of load carrying capacity. Also, stress distribution area beneath the footing increases due to wider dispersion of stresses affected by geogrid reinforcement in pond ash admixed with sand, which resulted in smaller settlement. This further leads to higher stiffness of pond ash admixed sand layer reinforced with geogrid reinforcement.

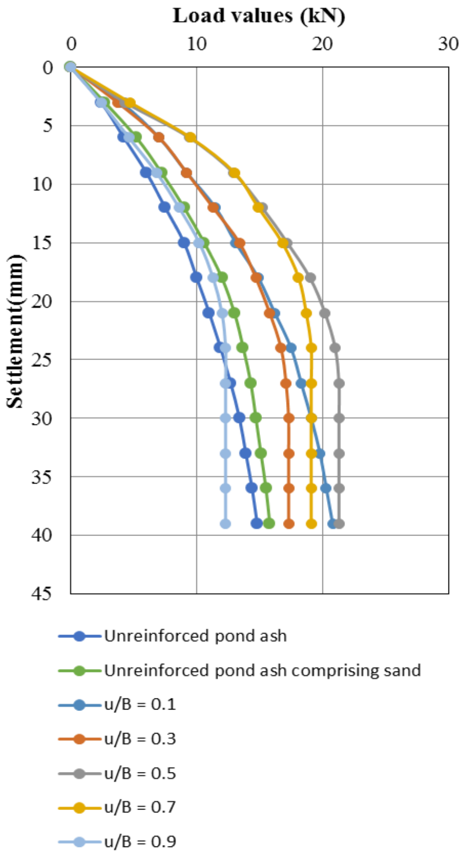


Figure 10. Load-Settlement curves for single layer (N=1).

Case 2, when N = 2

To study the effect of 2 layers of geogrid on sand admixed pond ash, the first layer of geogrid was kept at optimal depth of u/B = 0.5, as taken according to the above section. The depth of second layer was kept as H1/B = 0, 0.2, and 0.4 below the first layer of geogrid. The load settlement curve revealed that by reinforcing the sand admixed pond ash with second layer of geogrid, the load carrying capacity increased up to certain depth below the first layer of geogrid as shown in Fig. 11. The bearing strength of pond ash mixed with sand and embedded by two layers of geogrid by keeping H1/B = 0, 0.2, and 0.4 below the first layer of geogrid was 423, 475 and 443 kN/m^2, respectively. This stated that load carrying capacity increased up to H1/B =0.2 and afterwards it showed the downward trend revealing that optimal spacing for second layer of geogrid may be taken as 0.2 below the first layer of geogrid reinforcement. The percentage increase in bearing strength with two layers of geogrid reinforcement (H1/B = 0.2) was 150 % as compared with pond ash bed alone, 120 % percentage increment when compared with sand admixed pond ash, and same was 46 % when compared with single layer of geogrid reinforcement at u/B = 0.5. This may be due to the reason that stiffness of sand admixed pond ash reinforced with geogrid would be high when geogrid was placed near base of the footing as it intercepts the failure plane below the base of footing and this effect will reduce when the depth of reinforcement layer is raised below the base of footing.

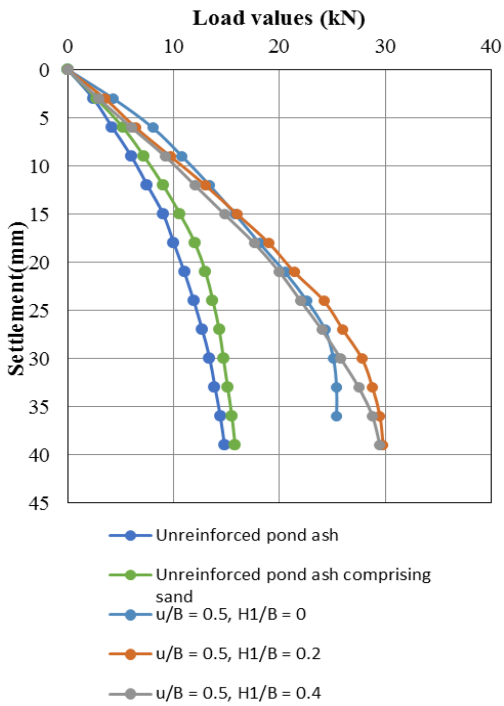


Figure 11. Load-settlement curves for double layers (N = 2).

Case 3, when N = 3

To strengthen sand admixed pond ash with 3 layers of geogrid reinforcement, the first and second layer was kept at optimal depth as calculated from above section and was kept as 0.5B (below the base of footing) and 0.2B (depth below the first layer of geogrid layer). The third layer of geogrid reinforcement was kept H2/B = 0, 0.2, 0.4, and 0.6 below the second layer of geogrid. The load settlement curve revealed that the load carrying capacity for sand admixed pond ash reinforced with three layers of geogrid increased for all depths as shown in Fig. 12. The bearing strength of the foundation bed comprised with three layers of geogrid at H2/B = 0, 0.2, 0.4, and 0.6 were 381.67, 520, 526, and 500 kN/m^2, respectively. This concluded that load carrying capacity enhanced only up to H2/B = 0.4 and then started showing the negative trend stating that optimal depth of third layer of geogrid may be taken as 0.4B below the depth of 2^{nd} layer of reinforcement. The percentage surge in the bearing capacity corresponding to three layers of geogrid was 176.8 % when compared to pond ash bed alone and 144.6 % when the same was compared with sand admixed pond ash.

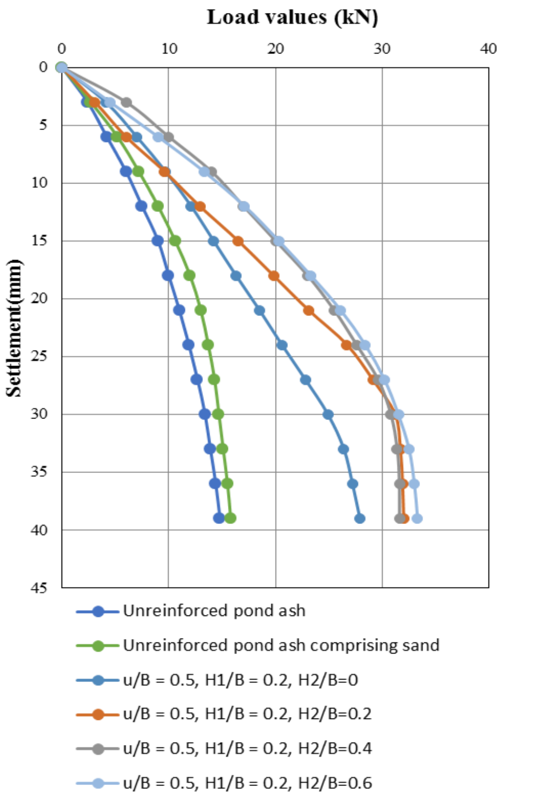


Figure 12. Load- Settlement curves for triple layers (N = 3).

Effect of geogrid reinforcement on BCR

Figure 13 shows the effect of number of geogrid layers on bearing capacity ratio (ratio of reinforced bearing capacity to unreinforced bearing capacity) of sand admixed pond ash. From the study, it is observed that the geogrid reinforcement is only effective near the base of the footing. This may be due to the fact that the geogrid layer near the base of the footing intercepts the failure plane and consequently leads to wider dispersion of stresses. Hence, it leads to the smaller settlement values corresponding to the applied load and resulted to higher stiffness of pond ash mixed with sand in optimal content reinforced with geogrid. Values of BCR corresponding to optimal depths of single, double, and triple layer of reinforcement were found as 1.51, 2.2, and 2.46, in respect. Further, the results of various testing parameters corresponding to different cases are shown in Table 6.

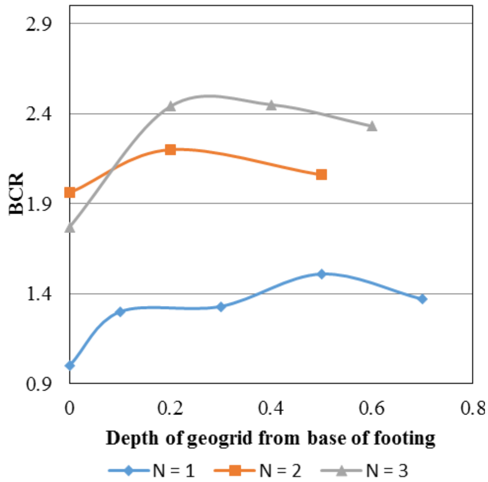


Figure 13. Effect of geogrid layer depth from base of footing on BCR.

Table 6. Bearing capacity and BCR for various testing parameters.

Single layer geo-grid depth u = f(B)	Double layer geo-grid depth H1 = f(B)	Triple layer geo-grid depth H2 = f(B)	Load carrying capacity (kN/m^2)	Perc. surge in bearing strength value	BCR values
-	-	-	215	-	-
0.1	-	-	281	30.6	1.3
0.3	-	-	286.6	33.7	1.33
0.5	-	-	**325**	**51.6**	**1.51**
0.7	-	-	295	37.2	1.37
0.9	-	-	205	-4.6	0.95
0.5	0	-	423	96.7	1.96
0.5	**0.2**	-	**475**	**120.9**	**2.2**
0.5	0.4	-	443	106	2.06
0.5	0.2	0	381.67	77.5	1.77
0.5	0.2	0.2	525	144.1	2.44
0.5	0.2	**0.4**	**526**	**144.6**	**2.46**
0.5	0.2	0.6	500	132.5	2.32

CONCLUSIONS

Based on the results obtained from the investigation, the following conclusions are drawn:

1. The replacement of pond ash by 15 % sand content in the mix increases mix density by 15 % and reduces the OMC by 14 % which consequently is taken as the optimal sand content.
2. After adding the sand content in optimal content, the bearing capacity increases by 13 % when compared to pond ash bed alone.
3. On reinforcing the sand admixed pond ash with geogrid layers, the load carrying capacity follows an upward trend with increasing in reinforcement layers.
4. The bearing capacity increases till the depth of first layer of reinforcement reaches the value of 0.5B below the base of footing and taken as optimal depth, 0.2B below the first layer of geogrid for two layers of reinforcement, 0.4B below the second layer of geogrid for three layers of reinforcement.

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