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Effect of Shape of Raft and Relative Density of Sand on Carrying Capacity of Model Piled Raft Foundation

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Abstract

A pile-raft foundation proves to be an economical foundation in many situations as compared to a pile foundation, but its analysis is complicated because of interactions between the pile, the raft, and the soil. This research paper presents the experimental study on an axially loaded model raft and piled raft foundation on sandy soil with different shapes of the raft (square, circular, rectangular, and trapezoidal). The study was carried out by varying the relative density of the sand bed (40%, 60%, and 80%). The spacing between piles was kept 7d for all model piled-raft foundations (MPRF). Initial Yield Load (IYL) and Final Yield Load (FYL) of MPRF were calculated as per the Poulos-Davis-Randolph (PDR) philosophy. It was observed that as the relative density of sand increases, the IYL and FYL of piled raft foundations of all shapes increase. The IYL and FYL were observed to increase with an increase in the relative density of sand in the MPRF for all shapes of raft. The higher IYL and FYL were observed mostly in MPRF with a square raft.

Keywords

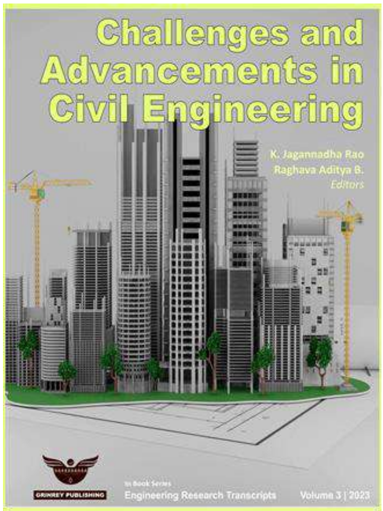
Final Yield Load; Initial Yield Load; model piled raft foundation

Received: 25 Mar 2023 | Accepted: 05 Sep 2023 | Online: 28 Sep 2023

Cite this article

Arpita Vimlesh Patel and Nitin H Joshi (2023). Effect of Shape of Raft and Relative Density of Sand on Carrying Capacity of Model Piled Raft Foundation, *Engineering Research Transcripts*, 3, 11-24.

DOI: https://doi.org/10.55084/grinrey/ERT/978-81-964105-0-6_2



1. Introduction

Piled raft foundations have been developed and are commonly used to support superstructures such as high-rise buildings, bridges, power plants, and other civil structures, as well as to prevent excessive settlements. The design of such foundations, however, has become complicated due to the load-sharing mechanism of the pile-raft-soil system. When compared to traditional pile foundations, where only piles are used to reduce total and differential settlements and the raft's contribution is generally ignored, the piled raft foundation method has been shown to be a cost-effective foundation type [7].

There are several studies found in the literature that focused on parameters such as the number of piles, length of piles, diameter of piles, pile spacing, positioning of piles, stiffness of piles, load distribution, load level, raft thickness, raft dimensions [1] [2] [3] [4] [5], and type of soil, but the shape of the raft with an equal contact area was missing. The goal of this research was to evaluate the performance of a model piled raft foundation lying on a sand bed with varying relative density and raft shapes with equal contact area.

2. Materials and methods

In this research work, laboratory model tests were conducted on unpiled raft and piled rafts with different shapes of raft supported on loose to dense sand conditions (RD = 40%, 60%, and 80%). The laboratory model tests were carried out on model rafts made up of mild steel plates with sizes of 220mm × 220mm × 25mm thick (Square Shape), 248.24mm diameter × 25mm thick (Circular Shape), 260mm ×186.1mm × 25mm thick (Rectangular Shape), 240mm (long side) × 230mm (cross side) ×180mm (short side) × 25mm thick (Trapezoidal Shape) .The contact area of all raft shapes was kept constant. In the laboratory test, model mild steel piles with hollow circular cross sections and 9.7mm external diameter, 0.95mm thickness, and a length of 291mm were used to represent the length to external diameter (l/d) ratio of 30. The bottom of the pile was kept in a closed cone with a 120° angle of cone. The piled raft was used, which consisted of a group of piles in a square pattern arrangement of 3x3 groups (9 piles) with 7d spacing located centrally screwed below the raft. To this end, an experimental setup was created to imitate the piled-raft foundation using various parameters. These are discussed in the following section:

2.1 Material Properties

2.1.1 Sand

Commercially available Orsang river sand was used as a foundation soil. Fig. 1 depicts the particle size distribution curve of Orsang river sand. The index properties and shear strength properties of sand are listed in Table 1.

2.1.2. Model pile

Mild steel rods with a hollow circular cross section having a 9.7mm external diameter, 0.95mm thickness, and length to external diameter (L/d) ratio of 30 were used as model piles (Fig. 2). The bottom part of the pile was a closed cone with a 120° angle. Threads were provided at the top end of the inner side of the piles to fix them to the raft using a screw from the top of the raft, generating monolithic action between the piles and the raft.

Fig. 1. Model pile

2.1.3 Model Raft

Mild steel plates were used to prepare the rigid model rafts. The dimensions of model rafts with different shapes are as shown in Table 2. Fig. 3 shows the detailed dimensions of a model raft with the arrangement of earth pressure cells (EPC) and piles. Small circle having 10mm diameter and big circle having 31mm diameter in Fig. 2 display the position of piles and EPC in MPRF respectively.

2.1.3 Model Piled Raft

The model piled raft was prepared by fixing the pile group below the raft. The pile group consisted of nine piles in a square pattern with centre-to-centre spacing between the piles 7d. The pile group was secured beneath the raft in such a way that the raft's centre of gravity and the pile group's centre of gravity coincided.

Table 1. Index properties and shear strength properties of sand

Sr. No.	Property	Unit	Values
1	Specific Gravity	-	2.55
2	Particle Size Distribution		
	Gravel (greater than 4.75mm size)	Percentage	2.08%
	Coarse Sand (4.75 mm – 2mm)	Percentage	2.2%
	Medium sand (2mm – 0.425mm)	Percentage	63.5%
	Fine Sand (0.425mm – 0.075mm)	Percentage	30.9%
	Silt (less than 0.075mm)	Percentage	1.3%
3	D_{10}	mm	0.25
4	D_{30}	mm	0.41
5	D_{60}	mm	0.70
7	Coefficient of Uniformity (Cu)	-	2.75
8	Coefficient of Curvature (Cc)	-	0.95
9	Type of sand as per IS code method (sieve analysis)	-	SP
10	Maximum unit weight	(kN/m^3)	18.3
11	Minimum unit weight	(kN/m^3)	15
12	Unit weight of sand at 40% Relative Density (RD)	(kN/m^3)	16.2
13	Unit weight of sand at 60% Relative Density (RD)	(kN/m^3)	16.8
14	Unit weight of sand at 80% Relative Density (RD)	(kN/m^3)	17.5
15	Angle of internal friction at 40% RD	degree	32
16	Angle of internal friction at 60% RD	degree	35
17	Angle of internal friction at 80% RD	degree	39

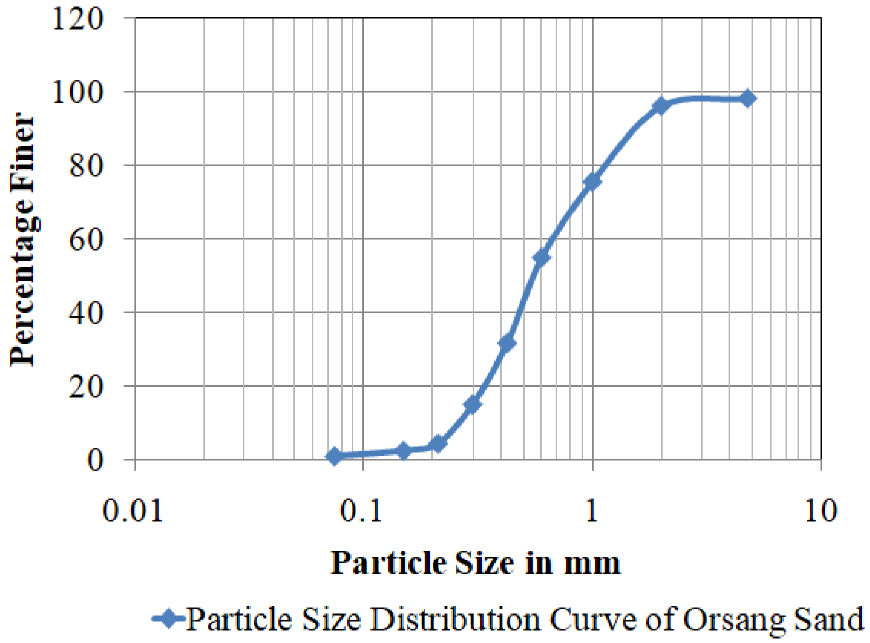


Fig. 2. Particle size distribution curve of the Orsang river sand (Sieve Analysis Test)

Table 2. Dimensions of different shape of model raft

Shape of model raft	Plan dimensions of model raft (mm)	Plan area of raft (mm^2)	Thickness of model raft (mm)
Square	220 x 220	48400	25
Circular	248.24 (Dia.)	48400	25
Rectangular	260 x 186.15	48400	25
Trapezoidal	Long side- 240 Short side- 180 Cross size- 230	48400	25

2.2 Experimentation

2.2.1 Experimental Set up

The model tests were performed in a tank that measured 1200 mm×1200 mm in plan and 1070 mm in depth and was made of mild steel plate, one-sided Perspex sheet, and angle stiffeners. The tank was supported by a reaction loading frame constructed of channel and angle sections. The mechanical screw jack was attached centrally on the top of the reaction frame, as shown in Fig. 4 and 5. A proving ring was held between the raft and the mechanical screw jack to measure the load. Four linear displacement transducers (LVDTs) with 0.01 mm accuracy were placed at the raft's corners to measure vertical settlement. Averaging the LVDT readings yielded the average settlement. Earth pressure cells (EPC) were placed in the groves at the bottom of the raft in such a way that the bottom surface of the raft and the EPC met in a plane, as shown in Fig. 3, to investigate the contact pressure distribution between the raft and the soil. The earth pressure cells were 30mm in diameter and 12mm in thickness.

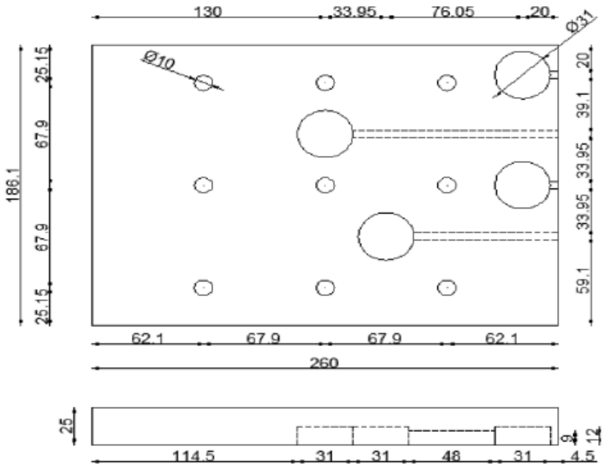
2.2.2 Testing Procedure:

The test procedure consisted of the following steps:

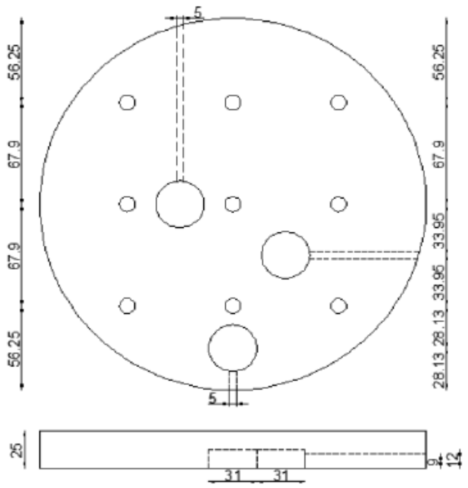
1. The tank's total height was divided into 50 mm intervals. The sand was filled in the tank in layers and vibrated with a surface vibrator for a specific time to achieve the desired relative density, the details of which are given in Table 3. The dimensions, weight, and frequency of the surface vibrator used are 320mm x 310mm, 16.9 kg, and 1400 rpm, respectively. The tank was filled up to a height of 800 mm with sand.
2. The sand was filled in layers in the tank until it reached 55 cm / 60cm thickness, at which point the combined model of the pied raft was kept such that the center of gravity of the raft aligned with the center of the mechanical screw jack using a plumb bob and spirit level for leveling on the sand bed. It was driven 5cm into the sand bed from its previous position by pressing it with the mechanical screw jack. The sand at the periphery of the raft was vibrated with a vibrator. For compaction in the central portion of the piled raft, the raft was removed from the top by unscrewing, and sand between the piles was compacted using a narrow, 10 mm-thick, 58mm-wide mild steel plate by tamping. The tank was filled up to 800 mm with the required relative density of sand, and the raft was reconnected with the piles such that it flushes with the surface of the sand bed. The density of the sand was checked by placing strong wooden boxes of 15 cm × 10cm × 7.5cm at different elevations within the tank.
3. The proving ring for measuring load on the raft/piled raft was placed in the center of the model, so that it coincided with the center of the mechanical screw jack. A small metal ball was kept between the proving ring and the mechanical screw jack so that the model could be subjected to concentric load. To calculate the settlement due to the applied load, four LVDTs with a sensitivity of 0.01 mm were placed at the four corners of the raft.
4. The maintained load test (MLT) method was used for all tests, and the load increment was kept at 1/10th of the estimated ultimate capacity of an unpiled or piled raft, as the case may be. The load increment was held until the rate of settlement became negligible (0.01 mm per 5 minutes). The procedure was repeated until the large progressive settlement was reached or failure was noticed.
5. When the readings were stabilized, the settlement and EPC readings were taken for each load increment.

Table 3. Details of parameters used to achieve the desired density of sand using surface vibration technique

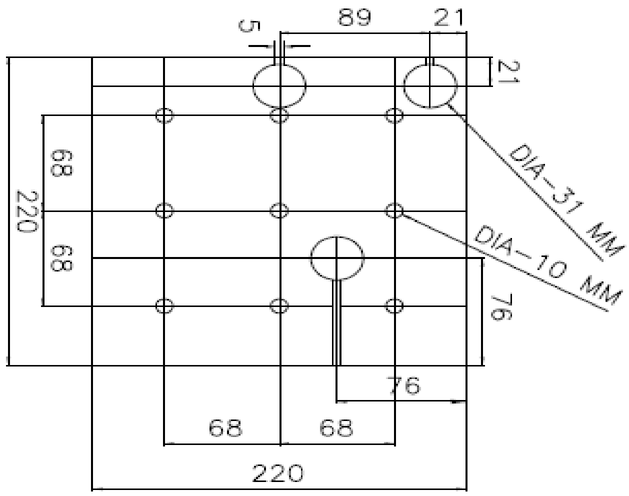
Sr.No.	Unit Weight (kN/m^3)	Relative Density (RD) (%)	Thickness of Layer (mm)	Mass of sand filled in each layer (kg)	Duration of Vibration (sec)
1	16.2	40	150	349.92	45
2	16.8	60	100	241.92	85
3	17.5	80	50	126	60



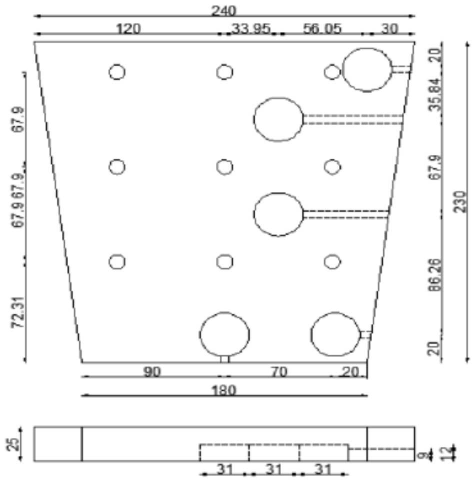
(a) Rectangular raft



(b) Circular raft



(c) Square raft



(d) Trapezoidal raft

Fig. 3. Detailed dimensions of model raft

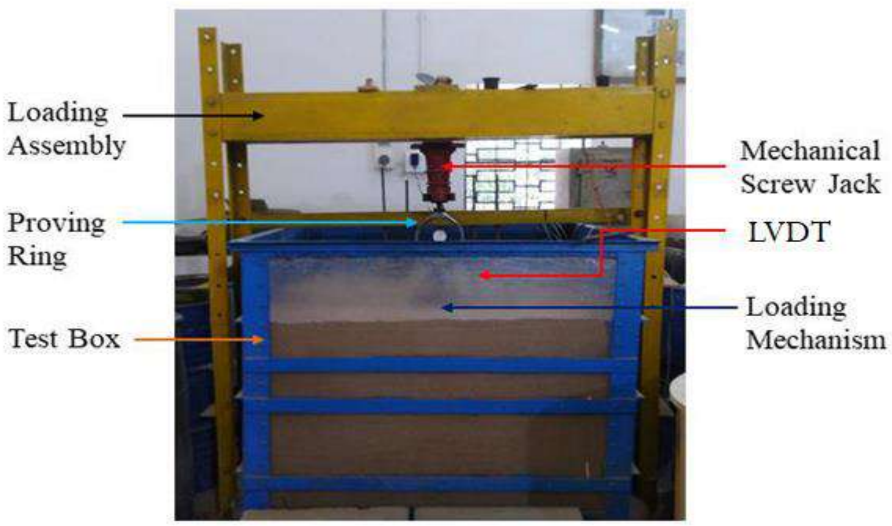


Fig. 4. Experimental Set up

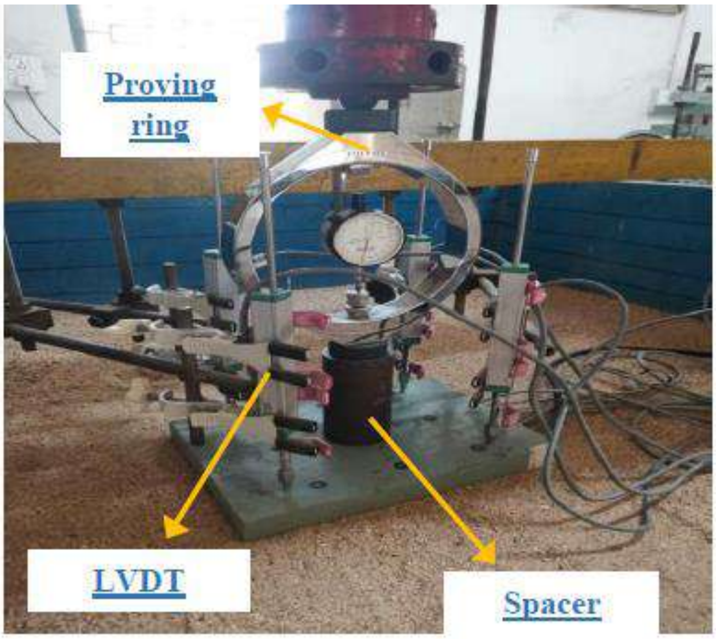


Fig. 5. Loading setup detail

3. Results and Discussion

3.1 Load settlement curve

The results obtained from experiments are analyzed as follows:

The analysis of unpiled raft (UR) was carried out as per the intersection tangent method, and the load settlement curve of a piled raft foundation was analysed as per the Poulos-Davis-Randolph (1980) Approach (tri-linear behaviour) generally known as the PDR method for piled raft foundation, as shown in Fig. 6 and 7, respectively.

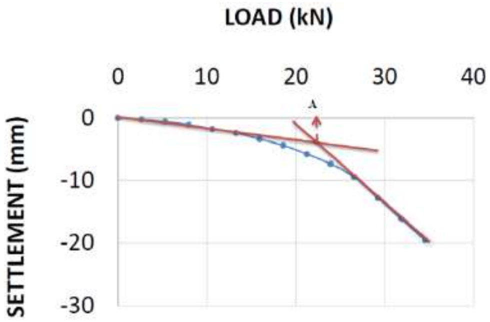


Fig. 6. Ultimate load of un-piled raft as per intersection tangent method

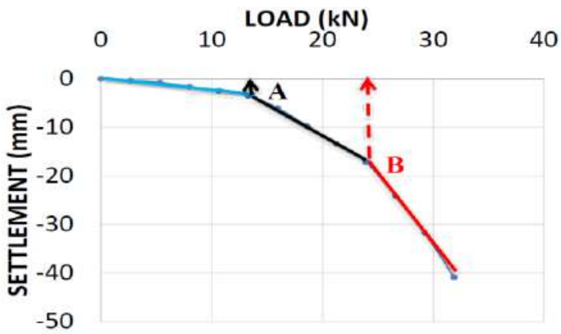
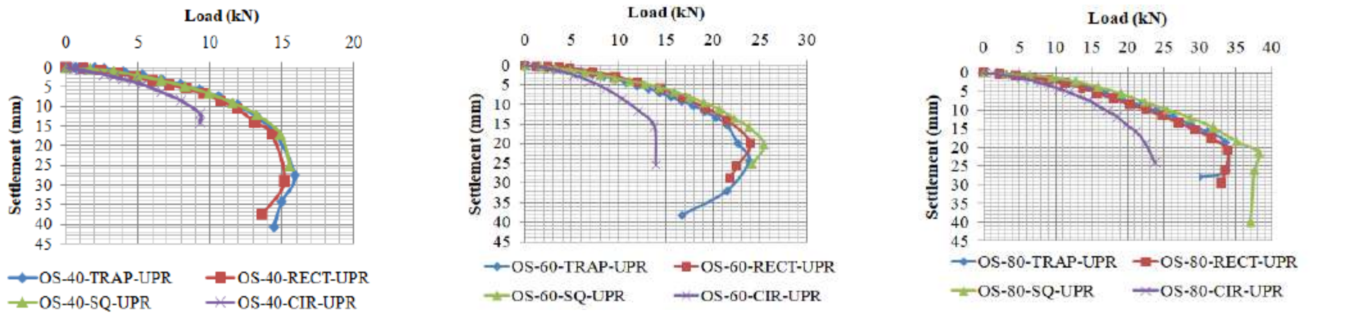


Fig. 7. Initial and Final yield load for piled raft foundation as per PDR method

The load-settlement behaviour of a piled raft foundation is considered tri-linear, according to the Poulos-Davis-Randolph (1980) Approach, also known as the PDR method. As illustrated in Fig. 7, the load corresponding to point A is referred to as the "initial yield load" (IYL), at which the piles of PRF yield, whereas the load corresponding to point B is referred to as the "final yield load" (FYL), at which both the raft and the piles of PRF yield [6].

3.1.1 Load settlement behaviour of model unpiled raft foundation

The load settlement curves of a model unpiled raft foundation (UPR) with different shapes of rafts at different relative densities of sand bed are presented in Fig. 8. It was observed that the load carrying capacity of circular rafts was lower than all other shapes at all relative densities. The load settlement characteristics of square, trapezoidal and rectangle shaped rafts were observed quite close to each other.



(a) 40% RD (b) 60% RD (c) 80% RD

Fig. 8. Load settlement curve of a model unpiled raft (UPR) foundation with different shapes of rafts at different relative densities of sand bed

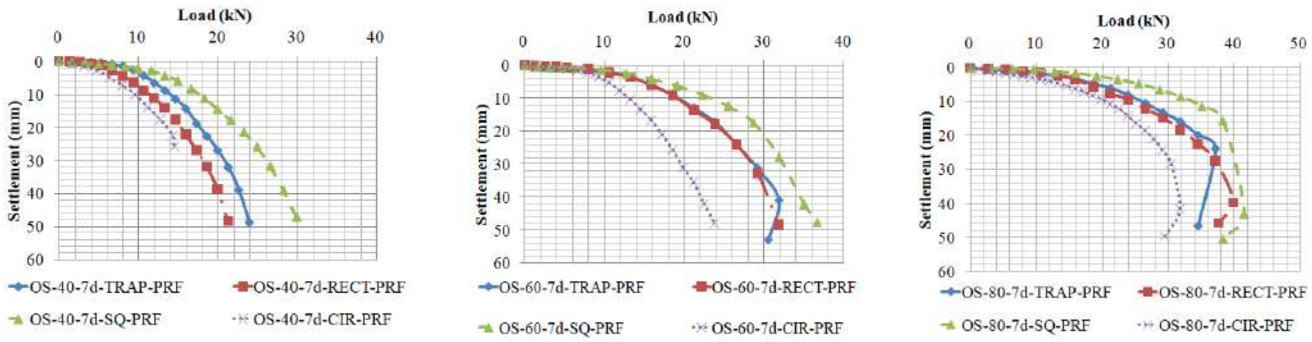
Table 4. Ultimate load of unpiled raft foundation (Qur) with different shape of rafts at different relative density of sand bed (RD)

RD	Ultimate Load(Qur in kN)				Percentage increment in Qur with respect to Qur of circular raft			
	Square Raft	Circular Raft	Rectangular Raft	Trapezoidal Raft	Square Raft	Circular Raft	Rectangular Raft	Trapezoidal Raft
40%	14.91	9.28	13.12	12.59	61	0.00	41	36
60%	25.45	10.34	23.92	23.86	146	0.00	131	131
80%	38.27	17.23	33.88	33.48	122	0.00	97	94

From Table 4, it is observed that the minimum and maximum ultimate loads of unpiled raft foundation at all relative densities of sand bed are obtained with a circular and a square raft, respectively. The range of percentage increment in Qur of square, rectangular, and trapezoidal rafts with respect to Qur of circular rafts was found to be 36% to 146%, as shown in Table 4.

3.1.2 Load settlement behaviour of model piled raft foundation

Fig. 9 displays the load settlement curve of a model piled raft foundation with different shapes of rafts at different relative densities of sand bed. The load settlement curve of a model piled raft foundation with trapezoidal, rectangular, and square shapes of raft was found to be similar up to a certain limit of load, but at higher loads it can be distinguished. As per the PDR method, the tri-linear behavior of the load settlement curve of a model piled raft foundation was observed, and the load corresponding to the end of the first linear portion where the capacity of piles is assumed to be mobilized is denoted as IYL (Initial Yield Load), and the load corresponding to the end of the second linear portion where the capacity of raft and piles is assumed to be mobilized is termed FYL (Final Yield Load).

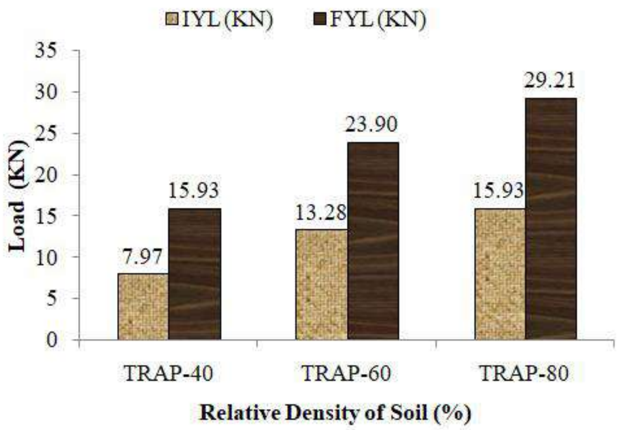


(a) 40% RD (b) 60% RD (c) 80% RD

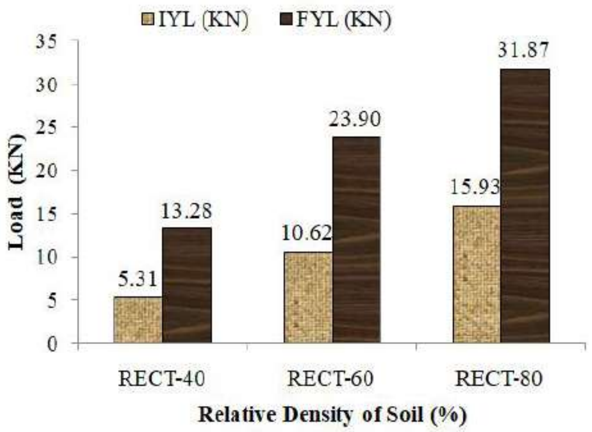
Fig. 9. Load settlement curve of model piled raft foundation with different shape of rafts at different relative densities of sand bed.

3.1.2.1 Initial Yield Load (IYL) and Final Yield Load (FYL)

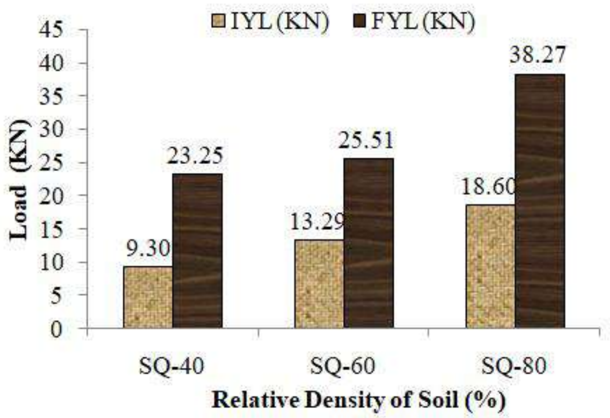
Fig.10 demonstrates the IYL (initial yield load) and FYL (final yield load) of a model piled raft foundation with different shapes of raft and different relative densities of sand bed. It can be observed from Fig. 10 that as the relative density of the sand bed increases, the IYL and FYL increase. In a model piled raft foundation, the IYL and FYL was found to be maximum with a square raft shape and minimum with a circular raft shape at all relative density of sand. The variation in IYL and FYL of MPRF with different shapes of rafts is shown in Table 5.



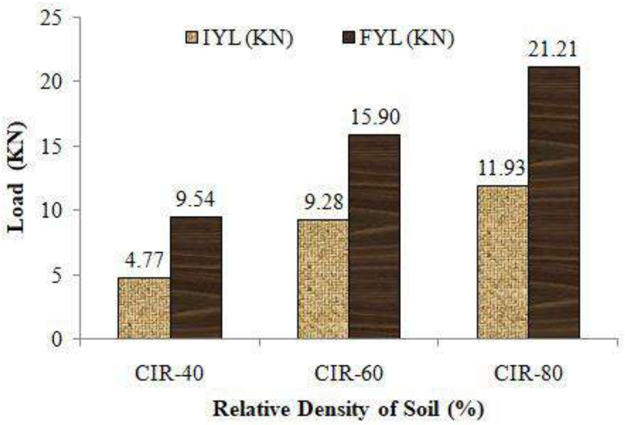
(a) Trapezoidal shape of raft



(b) Rectangular shape of raft



(c) Square shape of raft



(d) Circular shape of raft

Fig. 10. IYL (Initial Yield Load) and FYL (Final Yield Load) of model piled raft foundation with different shape of raft at different relative density of sand bed

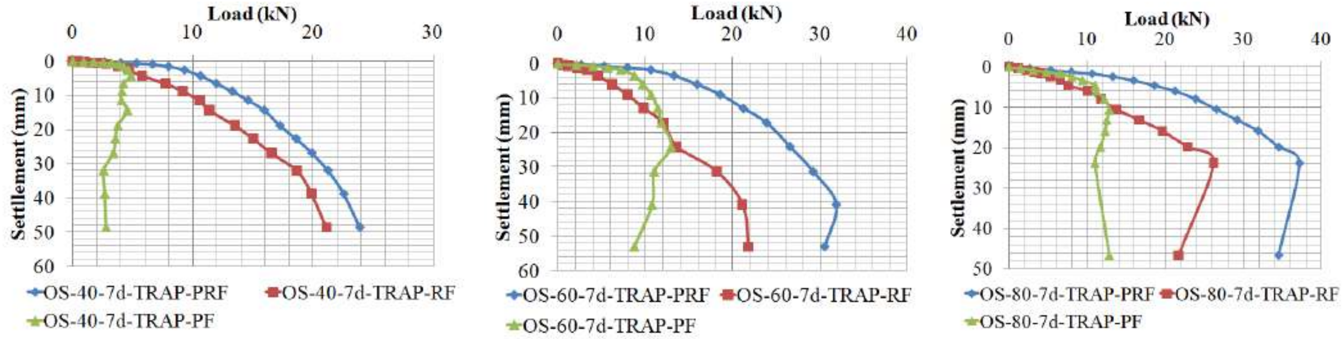
Table 5. Percentage increment in IYL and FYL of MPRF with different shape of raft as compared to MPRF with Circular shape of raft

RD of sand bed	Percentage increment in IYL of MPRF with different shapes of raft as compared to MPRF with a circular shape of raft			Percentage increment in FYL of MPRF with different shapes of raft as compared to MPRF with a circular shape of raft		
	TRAP	RECT	SQ	TRAP	RECT	SQ
40%	67	11	95	67	39	144
60%	43	15	43	50	50	92
80%	34	34	56	38	50	140

3.1.3 Load sharing mechanism

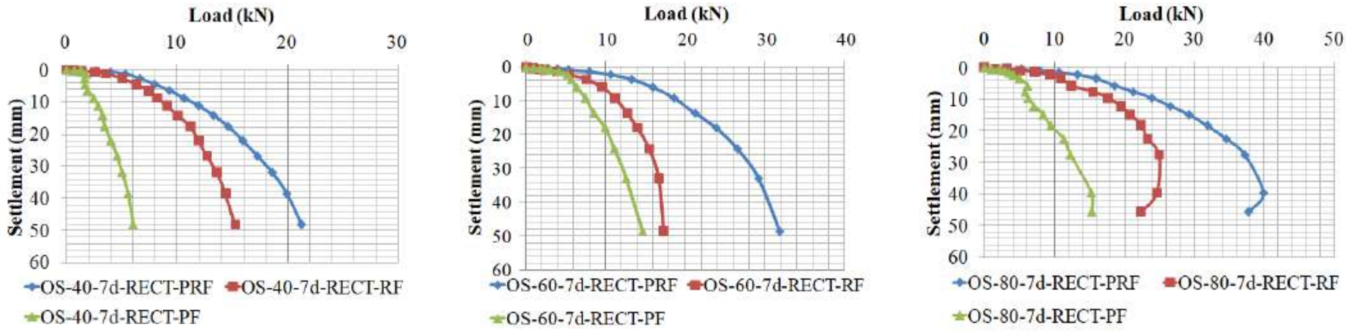
The load shared by the two components (pile group and raft) of the MPRF was calculated using EPC readings. The product of EPC readings in kPa and the contact area of respective region in the raft in m^2 give the load shared by the raft component in the MPRF, and the difference between the total applied load on the MPRF and the load shared by the raft gives the load shared by the pile group in the MPRF. The load shared by pile group was found to be greater in the initial stage of loading (up to IYL), and after that, increase in the contribution of pile group was found to be less. The proportions of load carried by rafts and pile group are clearly expected to vary as a function of settlement up to IYL and after IYL only the proportion of load carried by raft increased significantly with little improvement in load carrying by pile group[1][8].

Figs. 11 to 14 show load sharing between the pile group and raft in a model piled-raft foundation with different shapes of raft at different relative densities. The load shared by pile group and raft in MPRF with a trapezoidal shape at 40% RD is represented by the OS-40-7d-TRAP-PF and OS-40-7d-TRAP-RF lines, respectively. It is observed that the load shared by pile group is greater at the initial stage of loading up to a relative settlement (s/B) of 0.01 to 0.02 and that after, its contribution becomes less to nil and the contribution of raft increases except in square PRF at 40% RD and circular PRF at 60% RD.



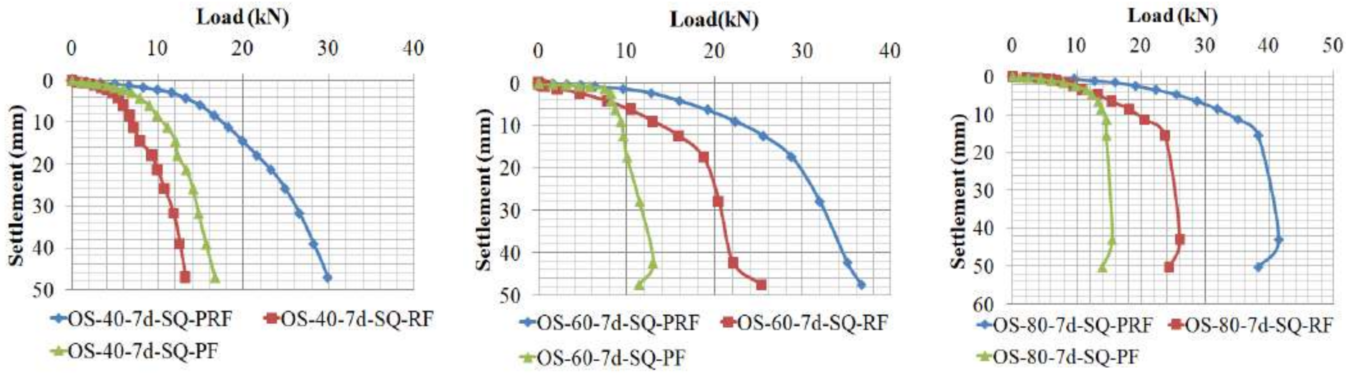
(a) 40% RD (b) 60% RD (c) 80% RD

Fig. 11. Load sharing between piles and raft in trapezoidal shaped model piled raft foundation



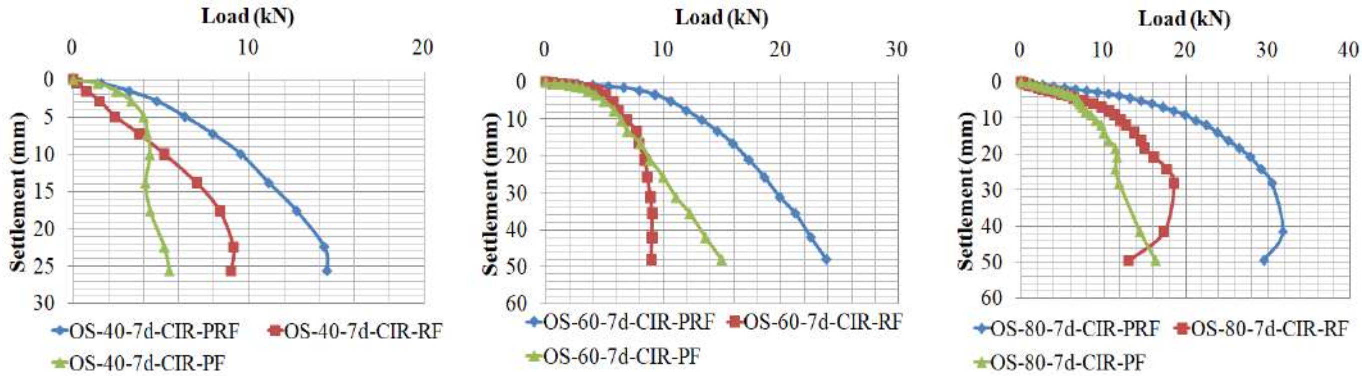
(a) 40% RD (b) 60% RD (c) 80% RD

Fig. 12. Load sharing between piles and raft in rectangular shaped model piled raft foundation



(a) 40% RD (b) 60% RD (c) 80% RD

Fig. 13. Load sharing between piles and raft in square shaped model piled raft foundation



(a) 40% RD (b) 60% RD (c) 80% RD

Fig. 14. Load sharing between piles and raft in circular shaped model piled raft foundation

3.1.4 Piled raft coefficient:

The ratio of load shared by pile group to the total applied load on a piled raft foundation is known as the piled raft coefficient (α_p). It was observed that as the settlement of MPRF increased, the piled raft coefficient decreased, supporting the results obtained by Horikoshi and Randolph [1]. The values of the piled raft coefficient (α_p) are higher initially and decrease non-linearly with increasing settlement. Within the initial settlement range, significant decrease in (α_p) is observed; up to s/B 0.01 to 0.02 support the results obtained by Junhwan Lee and others [2]. The load shared by pile groups and raft in MPRF, the piled raft coefficient, the relative settlement s/B (ratio of settlement to width of foundation), and variation in the piled raft coefficient at IYL and FYL are presented in Tables 5 and 6, respectively. The maximum value of α_p was found with a circular raft and minimum with a rectangular raft at IYL and 40% RD. At IYL, the α_p of circular and square raft decreases as the relative density of sand increases from 40% to 60%, and it increases from 60% to 80% RD. The α_p of rectangular and trapezoidal raft at IYL increases as the relative density of sand increases from 40% to 60% and decreases for the change in RD from 60% to 80%. The relative settlement (s/B) range for IYL was found to be 0.01 to 0.02.

Table 5. Load shared by pile group and raft, α_p and relative settlement (s/B) at IYL

Shape of raft and relative density	IYL (KN)	Load shared by raft in PRF at IYL	Load shared by piles in PRF at IYL	Piled raft coefficient	Settlement(mm)at IYL	s/B	% Variation in piled raft coefficient w.r.t 40%RD	% Variation in piled raft coefficient w.r.t circular shape of raft
CIR-40	4.77	1.24	3.53	0.74	2.92	0.01	0	0
CIR-60	9.28	5.08	4.20	0.45	3.44	0.01	-39	0
CIR-80	11.93	5.80	6.13	0.51	3.83	0.02	-30	0
SQ-40	9.30	4.34	6.29	0.59	4.12	0.019	0	-20
SQ-60	13.29	6.39	6.90	0.52	2.15	0.010	-12	+15
SQ-80	18.60	9.05	9.55	0.51	3.46	0.016	-13	0
RECT-40	5.31	3.53	1.78	0.33	1.20	0.01	0	-55
RECT-60	10.62	5.42	5.20	0.49	2.15	0.01	+46	+8
RECT-80	15.93	10.92	5.02	0.31	3.40	0.01	-6	-39
TRAP-40	7.97	3.72	4.24	0.53	1.53	0.01	0	-28
TRAP-60	13.28	4.54	8.74	0.66	3.49	0.02	+24	+46
TRAP-80	15.93	6.55	9.39	0.59	3.37	0.02	+11	+15

(+) indicates increments and (-) indicates decrements

Table 6. Load shared by pile group and raft, α_p and relative settlement (s/B) at FYL

Shape of raft and relative density	FYL (KN)	Load shared by raft in PRF at FYL	Load shared by piles in PRF at FYL	Piled raft coefficient	Settlement (mm)at FYL	s/B	% Variation in piled raft coefficient w.r.t 40%RD	% Variation in piled raft coefficient w.r.t circular shape of raft
CIR-40	9.54	4.33	5.21	0.55	10.02	0.04	0	0
CIR-60	15.90	7.88	8.03	0.50	16.70	0.07	-8	0
CIR-80	21.21	12.13	9.08	0.43	10.71	0.04	-22	0
SQ-40	23.25	7.96	10.65	0.57	12.31	0.06	0	5
SQ-60	25.51	13.26	8.00	0.38	17.91	0.08	-34	-25
SQ-80	38.27	19.74	12.15	0.38	15.50	0.07	-33	-11
RECT-40	13.28	10.03	3.25	0.25	14.13	0.08	0	-55
RECT-60	23.90	13.96	9.94	0.42	17.91	0.10	+70	-18
RECT-80	31.87	22.42	9.45	0.30	18.19	0.10	+21	-31
TRAP-40	15.93	11.37	4.56	0.29	14.33	0.08	0	-48
TRAP-60	23.90	12.03	11.87	0.50	17.14	0.10	+73	-2
TRAP-80	29.21	16.71	12.50	0.43	13.16	0.07	+49	0

(+) indicates increments and (-) indicates decrements

3.1.5 Comparison of behaviour of Unpiled raft and piled raft foundation:

The load settlement behaviour of a model unpiled raft foundation and a piled raft foundation was compared by comparing the load taken by the model unpiled raft foundation and the piled raft foundation at the same settlement value. The increment in load taken by the model piled raft foundation compared to the unpiled raft foundation was calculated in percentage and is denoted by PIL in Tables 7, 8, and 9. From the results, it can be observed that at very low relative settlement and at very high relative settlement the difference between the load carrying capacity of MPRF and UPR is higher and the difference decreases at intermediate relative settlement and with increase in the relative density.

Table 7. Percentage increase in load taken by MPRF as compared to UPR at 40% relative density

s/B	Settle ment (mm)	Shape of raft and relative density											
		TRAP-40			RECT-40			SQ-40			CIR-40		
		Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL
0.025	5.5	9.11	11.34	24	8.41	8.68	3	8.88	14.56	64	6.10	6.71	10
0.05	11	12.53	14.40	15	12.04	12.06	0	12.65	18.17	44	8.97	9.95	11
0.075	16.5	14.44	16.57	15	14.07	14.19	1	14.71	20.93	42	9.28	12.25	32
0.1	22	15.20	18.36	21	14.65	15.93	9	15.31	23.51	54	9.28	14.17	53
0.125	27.5	15.89	20.08	26	15.04	17.44	16	16.98	25.38	49	9.28	15.53	67

Where,
Qr = Load on model unpiled raft foundation (UPR),
Qprf = Load on MPRF,
PIL = percentage increment in load taken by MPRF with respect to UPR

Table 8. Percentage increase in load taken by MPRF as compared to UPR at 60% relative density

s/B	Settlement (mm)	Shape of raft and relative density											
		TRAP-60			RECT-60			SQ-60			CIR-60		
		Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL
0.025	5.5	12.30	15.37	25	13.76	18.44	34	14.03	18.07	29	8.11	10.76	33
0.05	11	18.45	19.90	8	19.27	25.45	32	20.47	24.27	19	11.72	13.54	16
0.075	16.5	21.81	23.49	8	22.55	30.55	36	24.09	28.14	17	13.80	15.83	15
0.1	22	23.24	25.76	11	23.38	34.26	47	24.41	30.11	23	13.90	17.49	26
0.125	27.5	22.86	27.81	22	22.06	37.19	69	24.18	31.79	31	15.13	18.97	25

Table 9. Percentage increase in load taken by MPRF as compared to UPR at 80% relative density

s/B	Settlement (mm)	Shape of raft and relative density											
		TRAP-80			RECT-80			SQ-80			CIR-80		
		Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL	Qr (kN)	Qprf (kN)	PIL
0.025	5.5	16.82	20.33	21	15.97	18.44	15	18.94	26.93	42	12.18	14.94	23
0.05	11	25.14	27.05	8	24.08	25.45	6	27.14	34.73	28	17.80	21.51	21
0.075	16.5	31.59	32.32	2	30.60	30.55	0	33.50	38.38	15	21.46	25.30	18
0.1	22	33.59	35.98	7	33.81	34.26	1	38.17	39.02	2	23.33	28.28	21
0.125	27.5	30.49	36.75	21	33.70	37.19	10	37.56	39.66	6	23.86	30.26	27

4. Conclusion

From this research work, the following conclusions were drawn:

1. The square shape of the raft is most preferable amongst the rafts studied in this study for unpiled rafts as well as piled raft foundations because its load-carrying capacity, or IYL and FYL, is found to be highest at all relative densities.
2. The circular shape of the raft is least preferable amongst the rafts studied in this study for unpiled rafts as well as piled raft foundations because its load-carrying capacity, or IYL and FYL, is found to be lowest at all relative densities.
3. The piled raft coefficient at IYL is found to be maximum in circular MPRF at 40% RD, and at 60% and 80% RD, it is found to be maximum in trapezoidal MPRF. i.e., at 40% RD, the contribution of piles in sharing the load applied on circular MPRF is greater, and at 60% and 80% RD, it is found to be greater in trapezoidal MPRF at IYL. The piled raft coefficient at FYL is found at its maximum in circular MPRF at all relative densities. i.e., the contribution of pile groups is found to be higher in circular MPRF as compared to other shapes of MPRF at FYL.
4. The PIL is found to be negligible in rectangular MPRF at 40% and 80% RD. i.e., at 40% and 80% RD, a rectangular raft is preferable to a rectangular PRF.

5. Acknowledgement

Partial financial support for this research work was received from the DST PURSE (Department of Science and Technology—Promotion of University Research and Scientific Excellence (Phase 2)) grant under grant agreement no. SR/PURSE Phase-2/28(G) dated 10/08/2018. The earth pressure cells and their indicator used in this research were purchased under this grant.

Abbreviations and Acronyms

s/B	:	ratio of settlement to width of model raft (relative settlement)
7d	:	Center-to-center distance between piles of a pile group in MPRF = 7 d (d = external diameter of pile)
Qp,u	:	Ultimate pile load capacity
Qprf	:	Load on MPRF
Qr	:	Load on model unpiled raft foundation (URF)
Qur	:	Ultimate load of unpiled raft foundation
α_p	:	Piled raft coefficient
ϕ	:	Angle of internal friction of sand bed (degree)
γ_d	:	Dry unit weight (kN/m^3)
CIR	:	*Circular shape of raft*
EPC	:	*Earth pressure cell*
FYL	:	*Final Yield Load (kN)*
IYL	:	*Initial Yield Load (kN)*
MPRF	:	*Model Piled raft foundation*
OS-40, OS-60, OS-80	:	*Orsang sand with 40%, 60 %, 80 % RD*
PF	:	*Load shared by pile group in MPRF*
PIL	:	*percentage increment in load taken by MPRF with respect to UPR*
PRF	:	*Total load applied on MPRF*
RD	:	*Relative density*
RECT	:	*Rectangular shape of raft*
RF	:	*Load shared by raft in MPRF*
SQ	:	*Square shape of raft*
TRAP	:	*Trapezoidal shape of raft*
UPR	:	*Unpiled raft foundation*
UR	:	*Unpiled raft*

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