IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ANALYSIS OF PILE CAPS USING SOFTWARE AND COMPARING RESULTS BY MANUAL DATA

[1]GADDIPALLI SHRAMIKA,[2] PROF. D. S. R.MURTY
[1]Assistant Professor, [2] Professor,
[1]Department of Civil Engineering
[1]Chaitanya Engineering College, [2]Andhra university, Andhra Pradesh, India

***Abstract**:* The important structural member, pile cap between the column and the piles, transfer forces coming from the column to the piles. A pile cap is a thick concrete mat that rests on piles that have been driven into soft or unstable ground to provide a suitable stable foundation. The concrete pile cap distributes the load of the building into piles. In this study total 9 models were studied which contain First series-four pile caps supporting on 2 piles. Second series-three pile caps supporting on 4 piles along edges. Third series-two pile caps supporting on 4 piles along column edges The pile cap is treated as beam in bending where the critical bending moment for the design for the bottom reinforcement are taken at the face of the column. Pile cap is analyzed by dividing into finite element using structural software for analysis and design (SAP2000).

Index Terms- Pile cap, unstable ground

.1. INTRODUCTION:

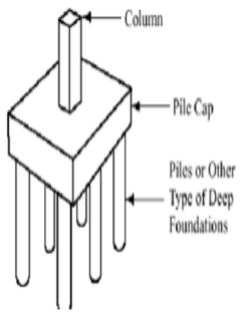
Pile caps are structural foundation elements that transfer the superstructure load to the piles. Their type depends on the load on the column base, the geotechnical capacity of the ground and the available building conditions and pile strength. For pile caps containing three or four piles, it is common to adopt triangle arrangement or square arrangement for piles respectively. However, in pile caps with many piles, the piles are equally spaced to create a rectangular base, generating situations in which the distance between the piles to the axis column is not the same. Although they are difficult to analyze while on operation, their fundamental for the superstructure security, so it is important to know their real behaviour. Situations in which the piles are not equally spaced in relation to the column axis, as the pile caps type analyzed, the structural behaviour is more complex and little known. The pile reactions may not have uniform values, because they depend on the pile cap stiffness, the ground and piles deformability.

As per IS 2911 (Part I/ Sec 3) -2010, the pile cap may be designed by assuming that the load from column is dispersed at 45˚ from the top of the cap up to the mid depth of the pile cap from the base of the column or pedestal. The reaction from piles may also be taken to be distributed at 45˚ from the edge of the pile, up to the mid depth of the pile cap. On this basis the maximum bending moment and shear forces should be worked out at critical sections.

A similar structure to the pile cap is a "raft" which is a concrete foundation floor resting directly the soft soil.

1.1 FUNCTIONS OF PILE CAP:

1. To distribute a single load equally over the pile group and thus over a greater area of bearing potential.
2. To laterally stabilise individual piles thus increasing overall stability of the group.
3. To provide the necessary combined resistance to stresses set up by the superstructure and/or ground movement



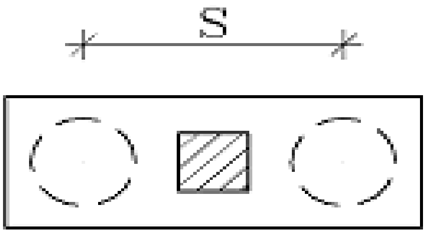
1.2 DESIGN PARAMETERS OF PILE CAPS:

1. Shape of pile cap.
2. Depth of pile cap.
3. Amount of steel to be provided.
4. Arrangement of reinforcement.

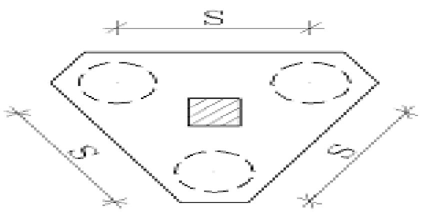
1.3 THE AMOUNT OF PILE CAP REINFORCEMENT IS GOVERNED BY:

1. The loading on the pile cap.
2. The spacing of the piles.
3. Depth of pile cap

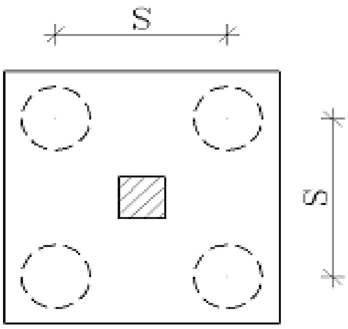
1.4 TYPICAL ARRANGEMENTS OF PILE CAPS:



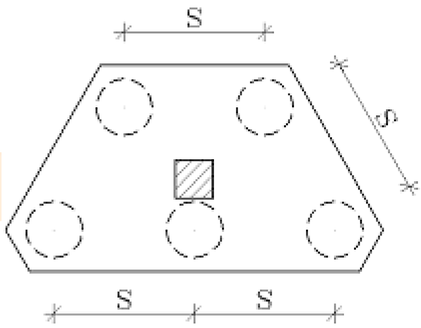
2 Piles



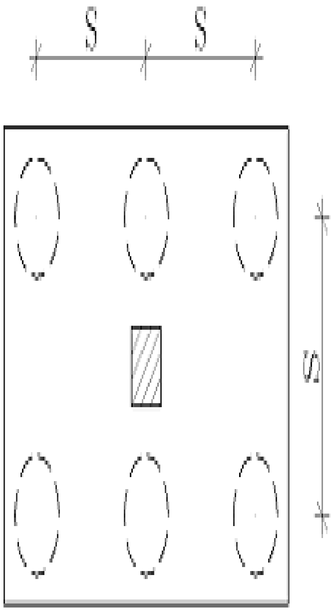
3 Piles

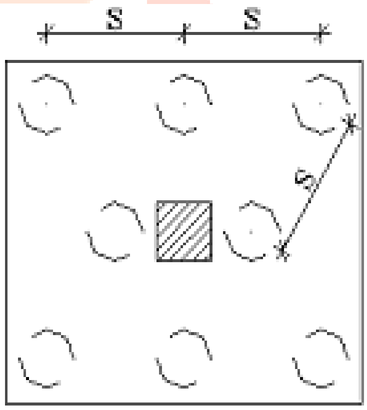


4 Piles

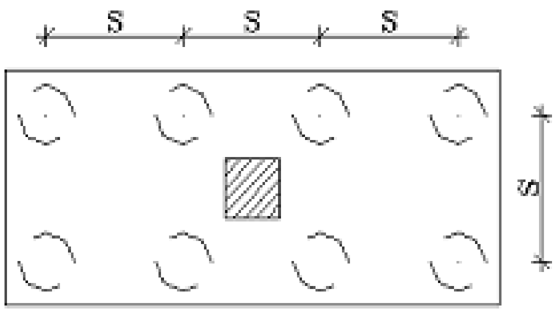


5 Piles

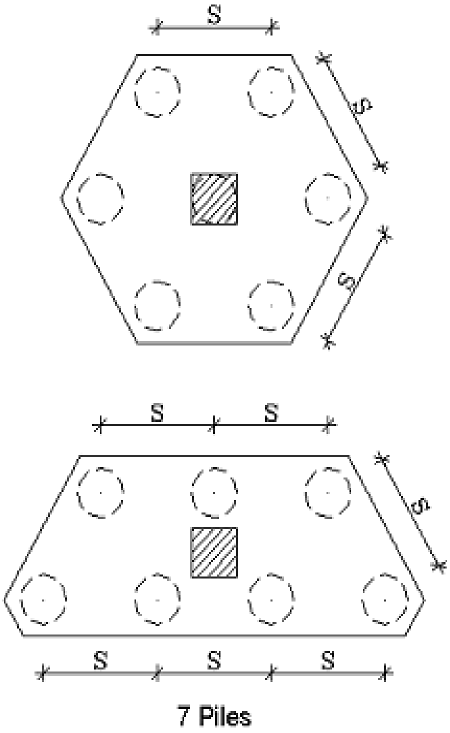


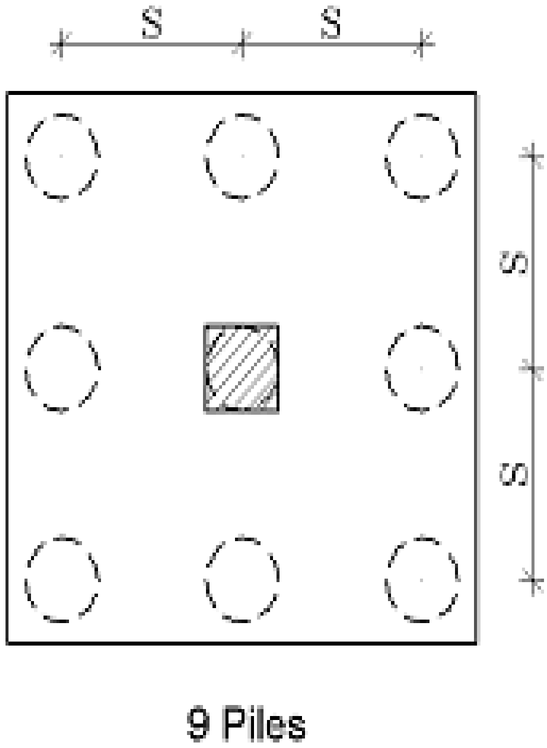


6 Piles



8 Piles





1.5 PRACTICAL ASPECTS ON PILE CAP DESIGN:

The structural design of a pile cap is similar to the design of spread footing. The load acting on the pile cap from the superstructure and piles are resisted by the developments of bending moment and shear force in the pile cap.

Codal provisions made in IS 2911(Part 1/sec3)-2010:

1. The size of the pile cap is fixed in such way that it has clear overhang beyond the outermost pile not less than 100mm, but preferably 150mm.
2. It should be deep enough to allow the necessary overlap of reinforcements from column and piles.
3. The clear cover to the main reinforcement should not be less than 40mm.
4. The span to thickness ratio of the cap should not be more than 5 so that pile cap is rigid enough to distribute the load uniformly to the piles.
5. Generally, its thickness should not be less than 500mm which may be reduced to 300mm at the free edges.
6. The piles should at least 50mm into the pile cap.
7. A levelling course of not less 75mm thick concrete should be provided under the pile cap.

2 .LITERTURE REVIEW

- **Anand Raj and Airin** studied pile cap (1000mm×1500mm×3200mm) which supports a column carrying axial load of 4320kN is designed using Bending theory, Truss analogy and Strut and Tie Model method. The pile cap is supported on two 700mm diameter piles. It was found that only flexural reinforcements have changed. Analytical modelling for the pile caps designed using the three methods was done in Ansys. The cost to strength ratio for the analytical model using Strut and Tie model was found to be least when compared to Bending Theory and Truss Method. The cost to strength ratio for the experimental model using Strut and Tie model was found least when compared to Bending Theory and Truss Method.
- **Oliveira et al** studied six reinforced concrete pile caps and numerical simulation and design by the Strut and Tie method. The finite element models were simulated using DIANA software. Although the analytical method showed good strength approximation for all cases, the distribution pile reactions should be analyzed for each specific case. The concrete strength increase enabled a pile cap strength gain, which is consistent with the hypothesis of analytical methods. However, varying the concrete strength did not alter the pile caps stiffness significantly.
- **Chandni Sheth** et al studied dynamic analysis of machine foundation. In this work, pile is chosen as supporting system for block foundation. The foundation system was simulated in SAP: 2000 VS.18 software and dynamic response of foundation was analyzed. For block foundation resting on soil, piles and soil can be modelled by spring elements, the dynamic behaviour can be represented accurately. It is recommended for block foundation to include the whole structure and replace the soil / piles by spring elements.

3. THEORY AND METHODOLOGY

- Pile cap is analysed using SAP2000.
- Codes that are used for the analysis:

SP-16.

IS 456-2000 plain and reinforced concrete.

IS 875(Part 5) code of practice for design loads.

IS 2911(Part 1/sec 1, sec 2, and sec 3):2010 Design and construction of pile foundation

- Loads considered for pile caps:

Dead load: The dead load is the self weight of the pile cap.

Live load: The live load is the load on the column.

4. MATERIAL PROPERTIES:

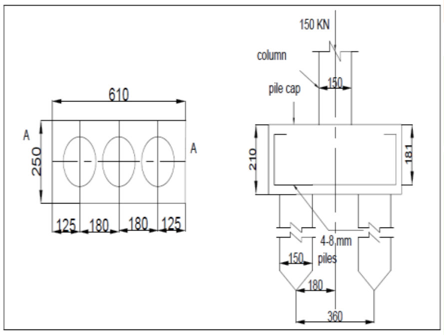
4.1 Concrete material properties

S.NO.	Parameter	Notation	Value
1.	Grade of concrete	f_{ck}	30N/mm²
2.	Unit weight		25 kN/m³
3.	Young's modulus	Ec	27.39×10^{6}kN/m²
4.	Poisson's ratio	μ	0.15
5.	Shear modulus	G	11.91×10^{6} kN/m²
6.	Coefficient of thermal expansion	A	9.9×10^{-6}/°C

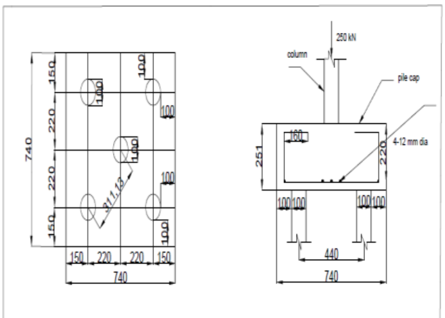
4.2 steel material properties

S.NO.	Parameter	Notation	Value
1.	Grade of Steel	f_y	415 N/mm²
2.	Unit weight		78.5 kN/m³
3.	Young's modulus	Es	200×10^{6}kN/m²
4.	Poisson's ratio	μ	0.3
5.	Coefficient of thermal expansion	A	1.17×10^{-5}/°C

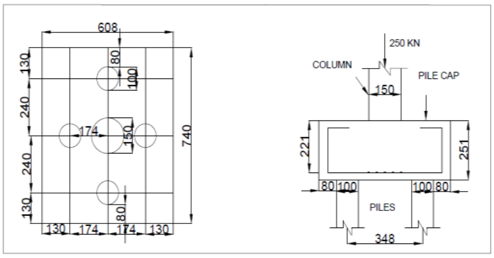
5. CROSS SECTION OF PILE CAPS:



Cross section view of first series



cross section view of second series



Cross section view of third series

5.1 TABULAR FORM OF FIRST SERIES

Label	Length of pile cap	Width of pile cap	Depth of pile cap	Distance between piles	Column diameter	Pile diameter	Load on columns
PC 1	610	250	210	360	150	150	150
PC 2	910	250	210	660	150	150	150
PC 3	1130	250	20	880	150	150	150
PC 4	1310	250	260	1060	150	150	150

5.2 TABULAR FORM OF SECOND SERIES

Label	Length of pile cap	Width of pile cap	Depth of pile cap	Distance between piles	Column diameter	Pile diameter	Load on columns
PC 5	740	740	251	440	100	100	250
PC 6	950	950	249	690	150	100	250
PC 7	608	608	250	348	150	100	250

5.3 TABULAR FORM OF THIRD SERIES

Label	Length of pile cap	Width of pile cap	Depth of pile cap	Distance between piles	Column diameter	Pile diameter	Load on columns
PC 8	740	608	251	348	150	100	250
PC 9	740	740	250	440	100	100	250

RESULTS AND DISCUSSIONS:

MANUAL CALCULATIONS

Providing 25 mm clear cover and using 8 mm dia bars

Effective depth of pile cap available; d = 210-25-4 = 181 mm

Lever arm for bending; distance from centre of the pile to face of the column =180-75=105mm

Dead load =0.25x0.610x0.210x25 = 0.8kN

Bending moment about column face (dead load) = 0.4 x0.105 = 0.042 kN m

Bending moment about column face (live load) = 75x 0.105=7.875 kN m

Bending moment about column face (dead load + live load) = (7.875+0.042) = 7.917 kN m

$Mu/ bd^2 = (7.917x1.5x10^6)/(250x181^2) = 1.45$

For M30 concrete and Fe 415 grade steel ,Table 4 of design hand book SP 16,percentage of steel Pt = 0.424 %

Area of steel = (0.424x250x181)/100= 192 mm^2

4 bars of 8 mm dia are used

Area of steel provided = 200 mm^2

Stiffness of spring = k = EA/L = = 161327.1 kN/m

E=young's modulus of concrete

A=Area of pile

L=length of pile

From the above fig

Bending moment about column face (dead load) = 0.0405 kN m

Bending moment about column face (live load) = 7.5993 kN m

Bending moment about column face (dead load+ live load) = 7.64 kN m

$Mu/ bd^2 = (7.917x1.5x10^6)/(250x181^2) = 1.45$

For M30 concrete and Fe 415 grade steel ,Table 4 of design hand book SP 16,percentage of steel Pt = 0.411 %

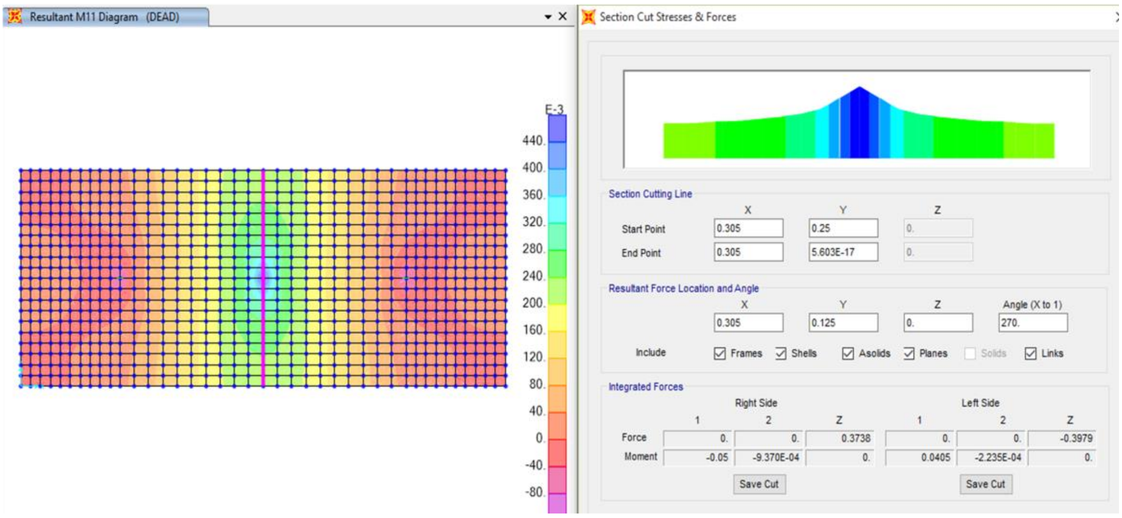
Area of steel = (0.411x250x181)/100= 186mm^2

4 bars of 8 mm dia are used

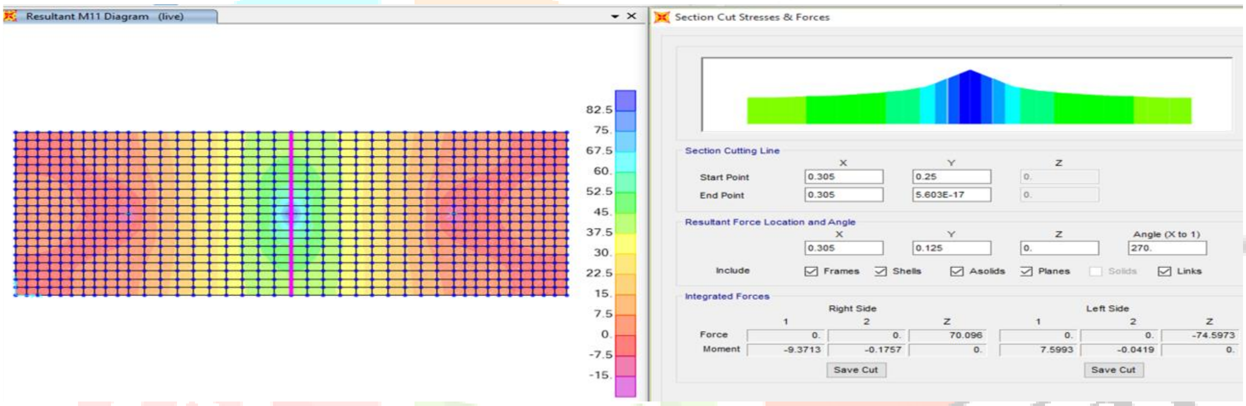
Area of steel provided = 200 mm^2

Software data

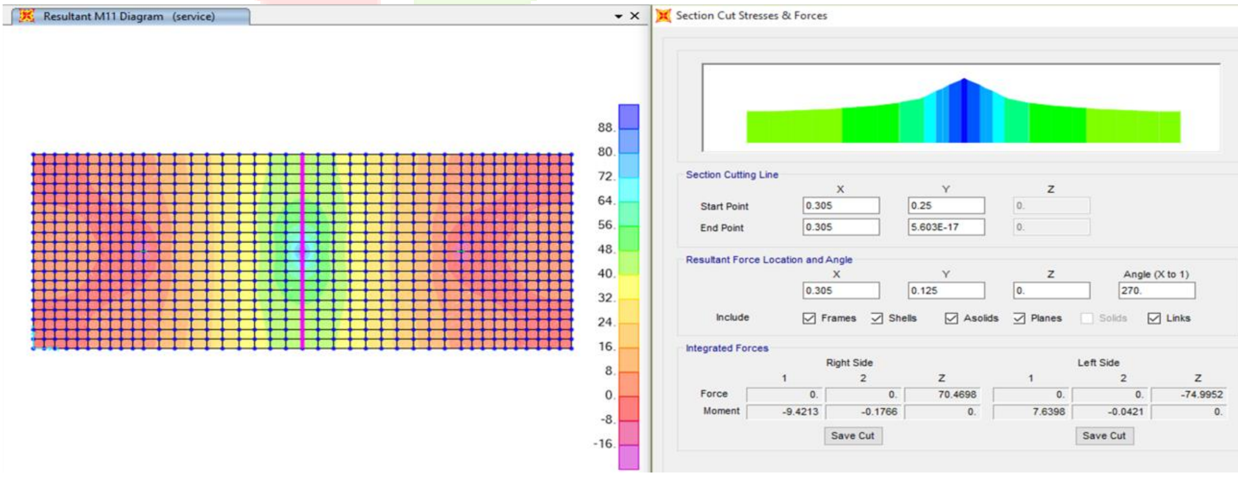
Section cut moment and force of PC 1(DL)



Section cut of moment and force of PC 1(LL)



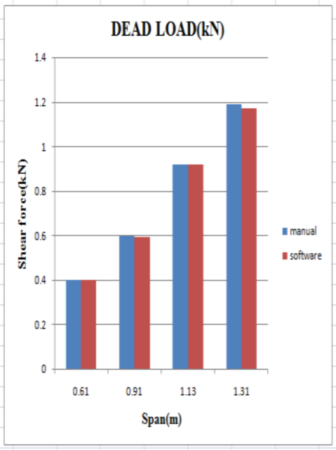
Section cut of moment and force of PC 1(DL+LL)

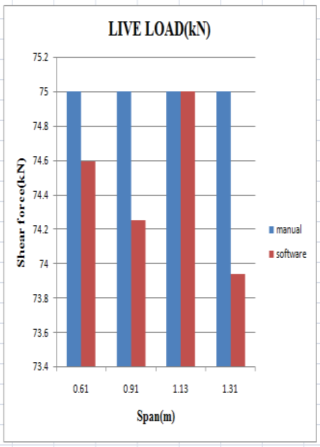


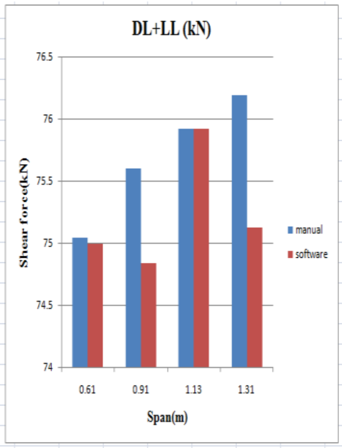
Comparison of Shear force and bending moment (kN) for DL,LL,(DL+LL) for first series

LABL E	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN)	SOFTWARE VALUES (kN)
PC 1	0.61 m	DL	0.400	0.398
		LL	75.00	74.59
		DL+LL	75.04	74.99
PC 2	0.91 m	DL	0.595	0.591
		LL	75.00	74.25
		DL+LL	75.59	74.84
PC 3	1.13 m	DL	0.92	0.920
		LL	75.00	75.00
		DL+LL	75.92	75.92
PC 4	1.31 m	DL	1.190	1.170
		LL	75.00	73.94
		DL+LL	76.19	75.12

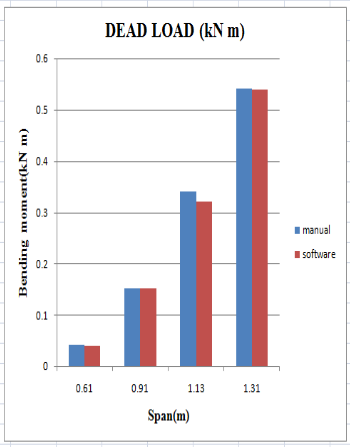
LABLE	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN m)	SOFTWARE VALUES (kN m)
PC 1	0.61 m	DL	0.042	0.040
		LL	7.875	7.600
		DL+LL	7.917	7.640
PC 2	0.91 m	DL	0.152	0.152
		LL	19.12	19.08
		DL+LL	19.28	19.24
PC 3	1.13 m	DL	0.340	0.320
		LL	27.37	26.40
		DL+LL	27.71	26.72
PC 4	1.31 m	DL	0.540	0.539
		LL	34.12	33.98
		DL+LL	34.67	34.52

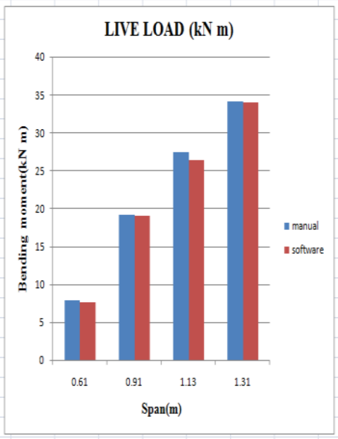


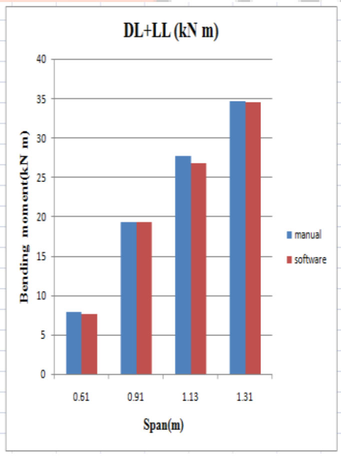




Shear force due to DL, LL, DL+LL of software data get reduced by 1%,1.4%,1.5% on comparing with manual calculations

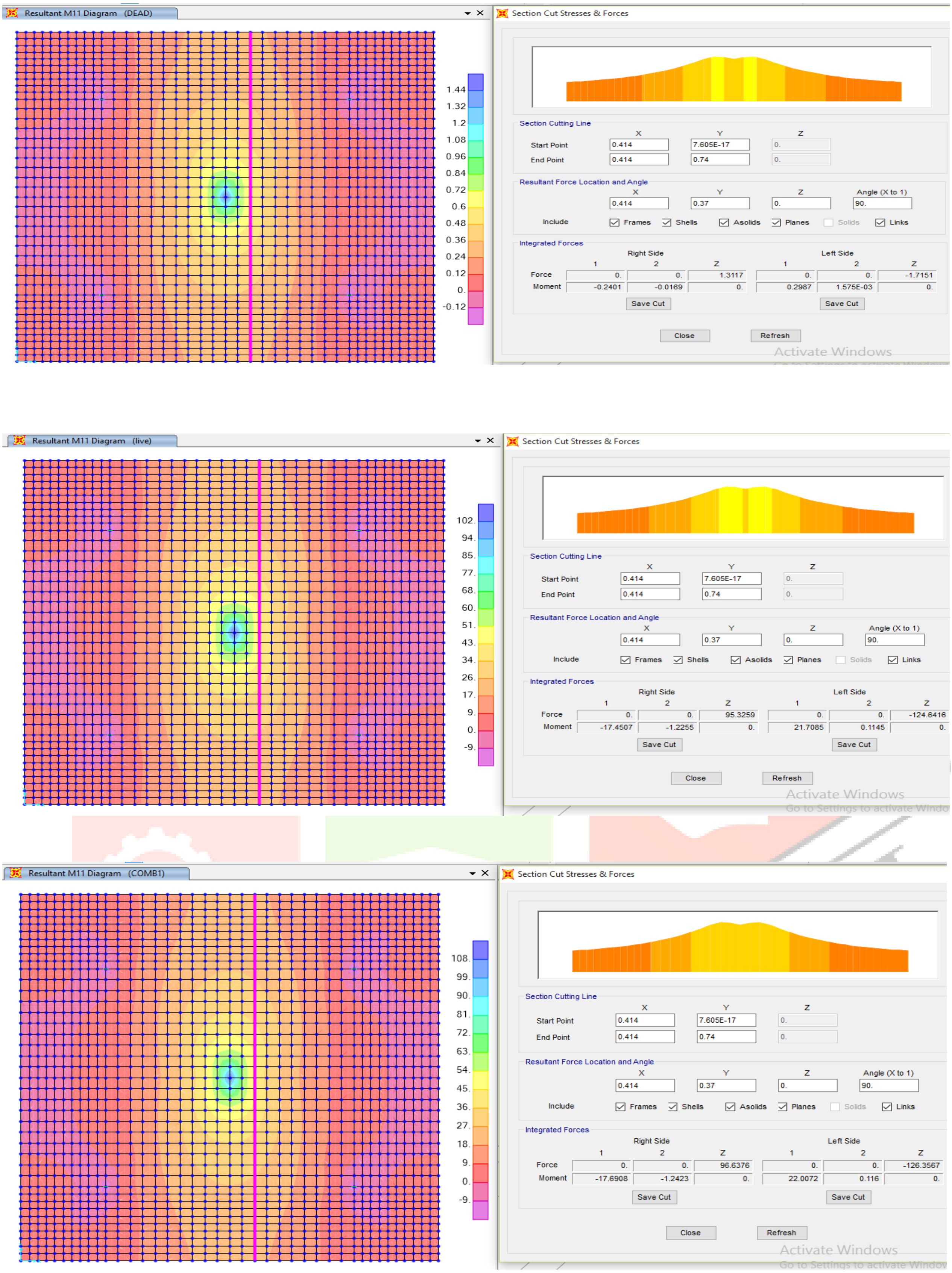






Bending moment due to DL, LL, DL+LL of software data get reduced by 4.5%, 4.5 %, 4 % on comparing with manual calculation

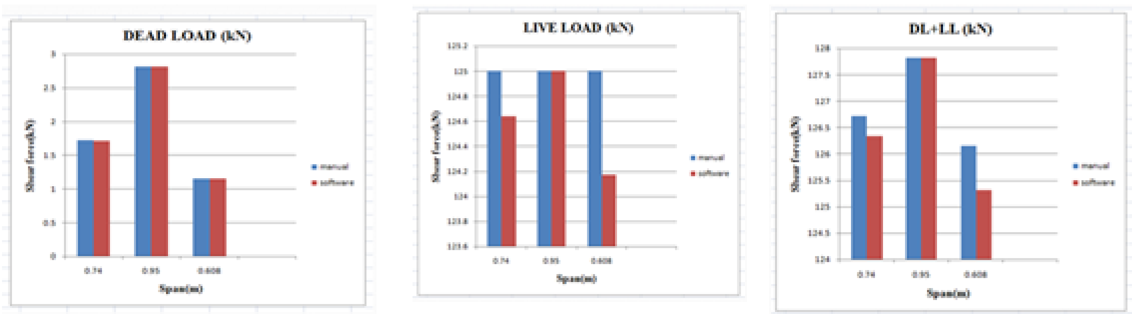
Section cut for shear force and bending moment of PC5 DL, LL, DL+LL for second series



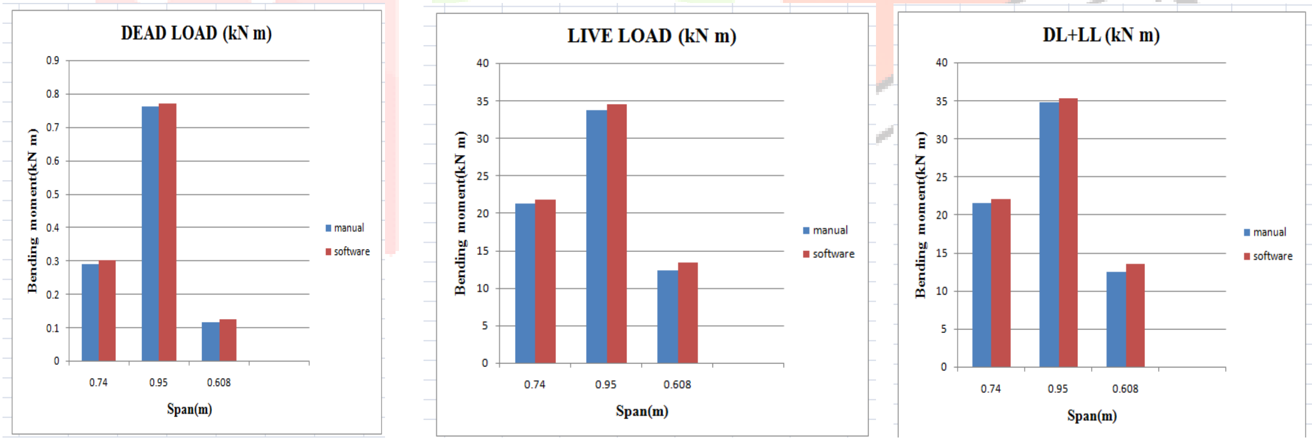
Comparison of Shear force and bending moment (kN) for DL,LL,(DL+LL) for second series

AB E	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN)	SOFTWARE VALUES (kN)
C 5	0.74 m	DL	1.72	1.71
		LL	125.00	124.64
		DL+LL	126.72	126.34
C 6	0.95 m	DL	2.81	2.81
		LL	125.00	125.00
		DL+LL	127.81	127.81
C 7	0.608 m	DL	1.15	1.15
		LL	125.00	124.17
		DL+LL	126.15	125.31

LABLE	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN m)	SOFTWARE VALUES (kN m)
PC 5	0.74 m	DL	0.290	0.300
		LL	21.25	21.71
		DL+LL	21.54	22.01
PC 6	0.95 m	DL	0.760	0.770
		LL	33.75	34.50
		DL+LL	34.51	35.27
PC 7	0.608 m	DL	0.114	0.123
		LL	12.37	13.33
		DL+LL	12.49	13.45

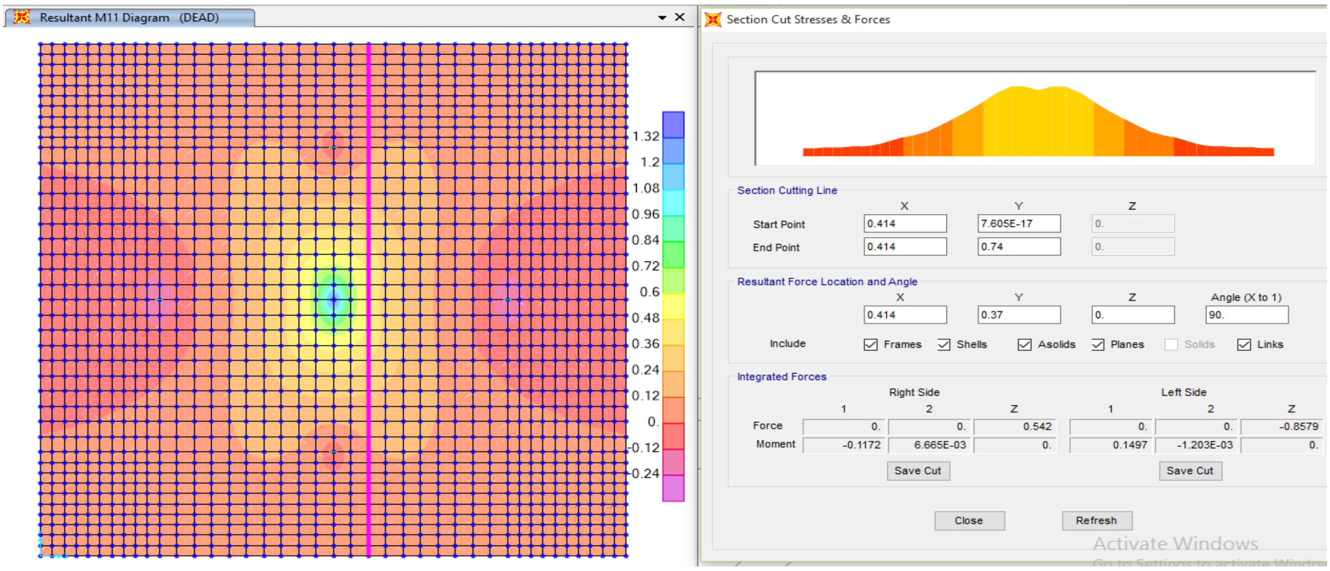


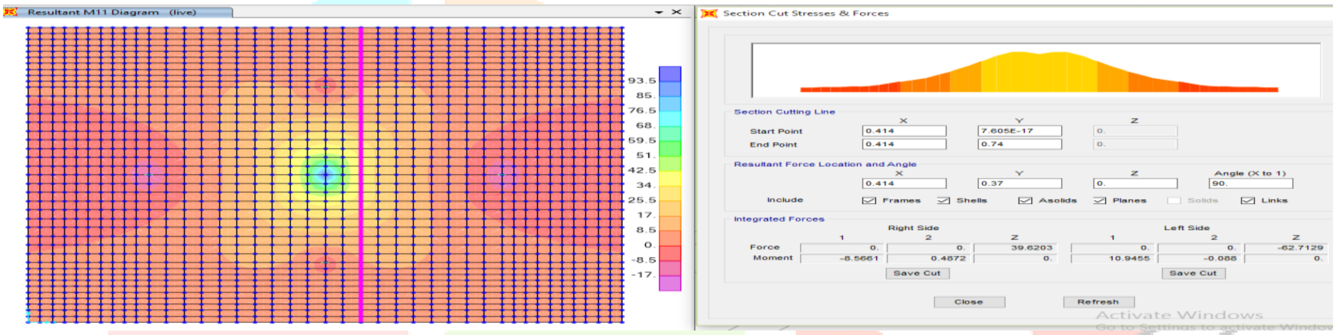
Shear force due to DL, LL, DL+LL of software data get reduced by 0.6%, 1%, 1.2% on comparing with manual data

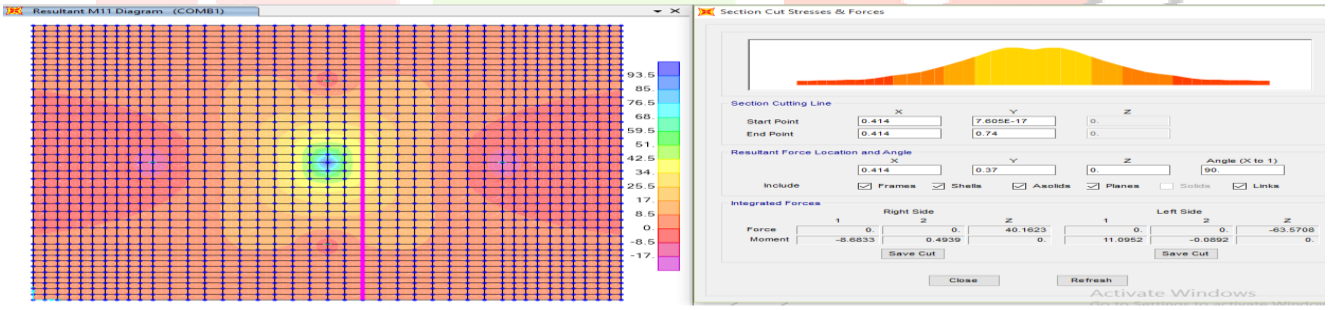


Bending moment due to DL, LL, DL+LL of software data get reduced by 6.5%, 7%, 7.8% on comparing with manual data

Section cut for shear force and bending moment of PC8 DL, LL, DL+LL for third series


Resultant M11 Diagram (DEAD)
1.32
1.2
1.08
0.96
0.84
0.72
0.6
0.48
0.36
0.24
0.12
0.
-0.12
-0.24
Section Cut Stresses & Forces
Section Cutting Line
X Y Z
Start Point 0.414 7.605E-17 0.
End Point 0.414 0.74 0.
Resultant Force Location and Angle
X Y Z Angle (X to 1)
0.414 0.37 0. 90.
Include Frames Shells Asolids Planes Solids Links
Integrated Forces
Right Side Left Side
1 2 Z 1 2 Z
Force 0. 0. 0.542 0. 0. -0.8579
Moment -0.1172 6.665E-03 0. 0.1497 -1.203E-03 0.
Save Cut
Save Cut
Close
Refresh


Resultant M11 Diagram (live)
93.5
85.
76.5
68.
59.5
51.
42.5
34.
25.5
17.
8.5
0.
-8.5
-17.
Section Cut Stresses & Forces
Section Cutting Line
Start Point 0.414 7.605E-17 0.
End Point 0.414 0.74 0.
Resultant Force Location and Angle
0.414 0.37 0. 90.
Integrated Forces
Right Side Left Side
Force 0. 0. 39.6203 0. 0. -62.7129
Moment -8.5661 0.4872 0. 10.9455 -0.088 0.
Save Cut
Save Cut
Close
Refresh

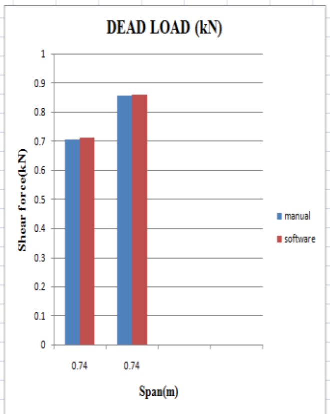

Resultant M11 Diagram (COMB1)
93.5
85.
76.5
68.
59.5
51.
42.5
34.
25.5
17.
8.5
0.
-8.5
-17.
Section Cut Stresses & Forces
Section Cutting Line
Start Point 0.414 7.605E-17 0.
End Point 0.414 0.74 0.
Resultant Force Location and Angle
0.414 0.37 0. 90.
Integrated Forces
Right Side Left Side
Force 0. 0. 40.1623 0. 0. -63.5708
Moment -8.6833 0.4939 0. 11.0952 -0.0892 0.
Save Cut
Save Cut
Close
Refresh

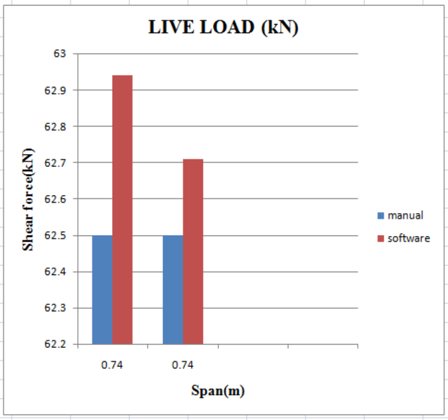
hear force for DL, LL, DL+LL for third series

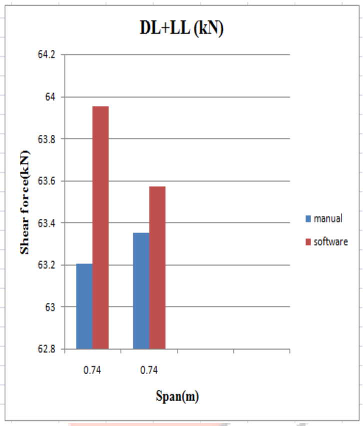
LABLE	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN)	SOFTWARE VALUES (kN)
PC 8	0.74 m	DL	0.705	0.710
		LL	62.50	62.94
		DL+LL	63.20	63.95
PC 9	0.74 m	DL	0.855	0.858
		LL	62.50	62.71
		DL+LL	63.35	63.57

bending moment for DL ,LL, DL+LL for third series

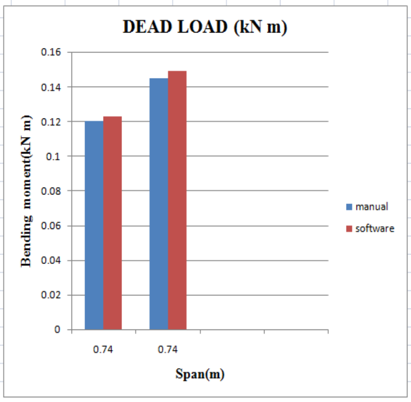
LABLE	LENGTH OF PILE CAP	LOAD TYPE	MANUAL VALUES (kN m)	SOFTWARE VALUES (kN m)
PC 8	0.74 m	DL	0.120	0.123
		LL	10.31	10.92
		DL+LL	10.43	11.04
PC 9	0.74 m	DL	0.145	0.149
		LL	10.625	10.94
		DL+LL	10.77	11.09

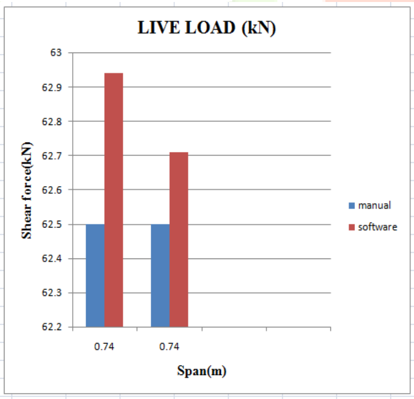


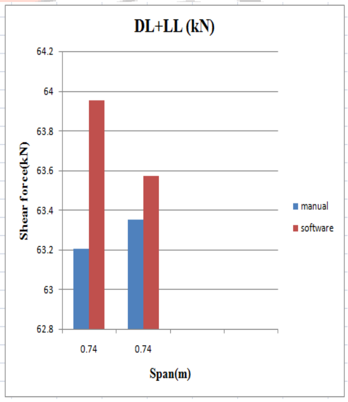




Shear force due to DL, LL, DL+LL of software get reduced by 0.7%, 0.7%, 1.2% on comparing with manual data







Bending moment due to DL, LL, DL+LL of software data get reduced by 0.8%, 5.8%, 5.9% on comparing with manual calculations

Conclusion

A study is performed on different spans of pile cap. In this study four pile caps with 2 piles, three pile caps with 4 piles along edges and two pile caps with4 piles along column line are considered for manually and software analysis. Following are the conclusions drawn from study.

- Pile cap is analyzed by manual calculation and using software for Dead Load and Live Load and (DL+LL).The value obtained from the manual calculation and from the software calculation are almost same. On further detail inspection, it was found that the Shear force and bending moment obtained from software data for (DL+LL) get reduced by 1.5% and 4.5% respectively when compared to manual calculations.
- Similarly, the Shear force obtained from software data for (DL+LL) get reduced by 1.2% when compared to manual calculations. But the bending moment obtained from software data for (DL++LL) get increased by 7.8% when compared to manual calculations.
- The Shear force and bending moment obtained from software data for (DL+LL) get increased by 1.2% and 5.9% respectively when compared to manual calculations.
- The net downward deflection was found to be within permissible limits as per prescribed value by IS code.

References

1. IS 456-2000 “Plain and reinforced concrete”.
2. IS 875(Part 5) “Code of practice for design loads”.
3. IS 2911(Part 1/sec 1, sec 2, and sec 3):2010 “Design and construction of pile foundation”.
4. SP-16 “Bureau of Indian standard; Design aids for reinforced concrete.
5. ACI 318-08 “Building code requirements for structural concrete and commentary”.
6. Varghese P.C (2004) Limit state design of reinforced concrete
7. Chandni Sheth, Dr. S.J. Shukla, Dr. A. K. Desai International Journal of Innovative Research in Science, Engineering and Technology Vol. 6, Issue 6, June 2017.
8. Varghese P.C Design of reinforced concrete foundations, first edition.
9. Varghese P.C Foundation engineering.
10. Charles Reynolds and James Steedman Reinforced concrete design, 10th edition