Study on the Behavior of Pile Cap Model with Various Type Failure of Concrete Cap

*Ambareesh Kumar
Dept. of Civil Engineering,
M.M.M. Engineering College,
Gorakhpur, India.
Email: ambar006@gmail.com

ABSTRACT: The ability of pile caps to resist vertical loads is often neglected in the design of pile groups to support buildings and bridges, although these caps are often massive and deeply buried. Neglecting cap resistance can result in excessively conservative estimates of pile group deflections and bending moments, exceeding the actual deflections and bending moments by 100% or more of pile cap failure. This paper present the result of pile cap failure of deferent type cracks and the show cracking load and failure load of concrete pile caps. It is clear that the behavior of pile groups subjected to vertical loads can be reflected more accurately in design if the lateral-load resistance of pile caps is better understood.
The pile cap design of three batches at (one batches 3 sample) nine samples. There are define at PC-1, PC-2 and PC-3. In addition to the samples shown in the section, the whole report of crack distributions at the failure steps for all the samples in Batch 1 and 2 and the crack characteristics and types discussed below are shown and annotated in paper.
Keywords: failure load, cracking load and cracking pattern.

INTRODUCTION

In total, three batches of samples were tested (Table 1). In order to clarify the identity of all pile caps, samples in different batches were numbered in an efficient way, generalized as: 'PC-NA'. The first 'PC-1' represented 'Batch' followed by 'PC-1A to PC-1C' representing batch number (from 1 to 3). The third 'PC-2' was the cap series being either PC-2A to PC-2C. The final 'PC-3' was the sample number within each cap series. For example, PC-3A to PC-3C meant the 3rd sample in Batch 3 Series A. The design strategy for sample dimensions is sketched in Figure (1). [1]

As mentioned in Section, the key parameters influencing between IS 2911 are the loading and depth of pile cap. The dimensions of the pile cap samples were designed to obtain a range of values of design vertical load on the pile cap. A constant by varying the longitudinal pile spacing and keeping the transverse pile spacing constant.

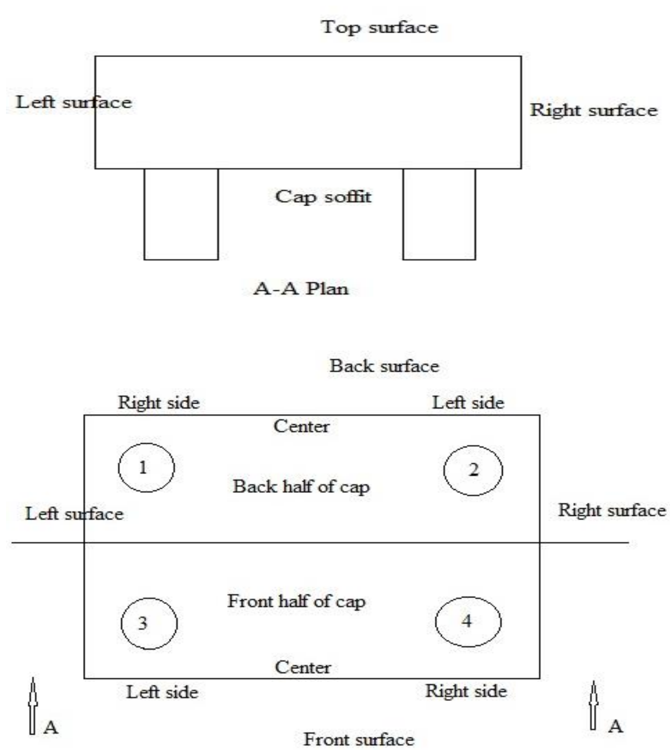


Figure-1 Terminologies for describing the crack distribution and propagation

Table: 1– Sample dimensions and reinforcement arrangement

Pile cap No.	Pile cap depth h mm	Effective cap depth d mm	Pile cap length l mm	Pile cap width b mm	Pile diameter h_p mm	Longitudinal pile Spacing kh_p mm	Transverse pile Spacing kh_w mm	Vertical loading Width h_c mm
PC-1A	130	110	1000	1000	100	800	800	250×250
PC-1B	130	110	1000	1000	100	800	800	250×250
PC-1C	130	110	1000	1000	100	800	800	250×250
PC-2A	150	130	1000	1000	100	800	800	250×250
PC-2B	150	130	1000	1000	100	800	800	250×250
PC-2C	150	130	1000	1000	100	800	800	250×250
PC-3A	170	150	1000	1000	100	800	800	250×250
PC-3B	170	150	1000	1000	100	800	800	250×250
PC-3C	170	150	1000	1000	100	800	800	250×250

Crack distributions at failure step

The first characteristic of the concrete pile cap crack distributions discussed in the following paragraphs was that under vertical loading, for caps with small transverse pile spacing, the crack distributions on front and back surfaces at failure were similar to those expected for 1-way shear failure, and the cap behaved close to 1-way shear behavior.

Result and discussion

Crack propagations

In all samples, cracks initiated with the bending cracks from the cap mid-span. The occurrence of the cracks in the experiments is a debatable point. In relatively deep caps as in the experiments, the cracks were less apparent and less densely distributed, but still did occur, in a form shorter and steeper than in a shallow pile. The cracks started at the cap soffit near the first bending crack and then extending upwards at an angle towards the edge of the vertical loading e.g. on PC-1A back surface (Figure-5). [6]This propagation normally occurred for a while and then stopped, being superseded by the propagation of the compressive splitting shear crack. This was because the short span constrained them from fully maturing, and the formation of the concrete compressive strut preceded the appearance of arch action which is deemed as a result of maturing cracks.

Cap deflection

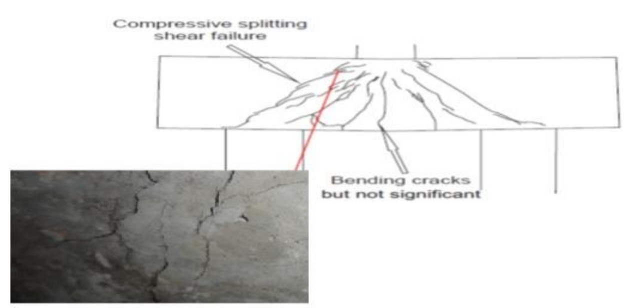
The early bending and shear cracks appearing in the cap in the elastic stage did not change the initial stiffness of the cap. The deflection of the center of the cap soffit increased linearly and remained in a small range, not more than 5. The deflection suddenly increased after the onset of the yield stage, the point that was normally marked by the beginning of the maturing of the critical shear crack or the central bending crack on the front or back surfaces.

The deflection could be very large in the yield stage before the structure finally failed, implying the failure was rather ductile. This could either be because of the yield behavior of the longitudinal reinforcement in bending failure or a gradual softening of the compressive concrete strut in the shear failure. This proved that in structures of short shear span, even in the absence of shear reinforcement, shear cracking does not necessarily result in immediate failure. The ductile behavior in pile caps with large transverse pile spacing may also be because of the cap's transverse behavior i.e. the ductile behavior of the transverse reinforcement which caused the cap to remain ductile even when the shear crack on the cap front and back surfaces appeared.

Table: 2- Pile cap testing on cracking load and failure load

Batch		Design load (KN)	Cracking load (KN)	Failure load (KN)
Batch-1	1-A	50	100	205
	1-B		93	196
	1-C		89	185
Batch-2	2-A	75	140	247
	2-B		146	249
	2-C		155	235
Batch-3	3-A	100	189	362
	3-B		180	368
	3-C		210	374

A compressive splitting crack also appeared and was fully developed on the back surface left side in PC-3A (Figure-2) and on the front surface right side in PC-1A and PC-2A. These cracks initiated near the middle of the inclined crack. It was only on PC-3C front (Figure-10) and back surfaces and on PC-2C front surface right side (Figure-8) that the widely opened compressive splitting crack initiated from the huge crushing of the concrete under vertical loading where the concrete severely spelled off. In most samples, the central bending crack linked the front and back surfaces of the cap on the cap soffit (Figure-4).



Concrete being crushed under vertical loading

Figure-2 Crack distribution on PC-3A front surface at failure step

As shown in Figure, for PC-2B, Crack (a) was definitely a bending crack induced by bending moment in the transverse direction. This was ensured by its shape on the right surface (Figure-3) which was vertically upwards rather than inclined. Crack (b) indicated the behavior around as individual corner pile. Its shape of the right and left surfaces was inclined and short. It might be a potential punching shear crack caused by the individual pile. A similar crack also appeared in PC-2C (Figure-8) and PC-3C. However, no pile cap finally failed by the punching shear failure of the corner pile. The type of Crack (c) is between a bending crack and punching shear crack.

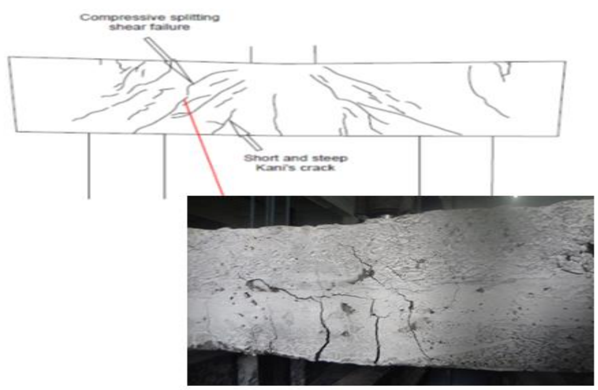
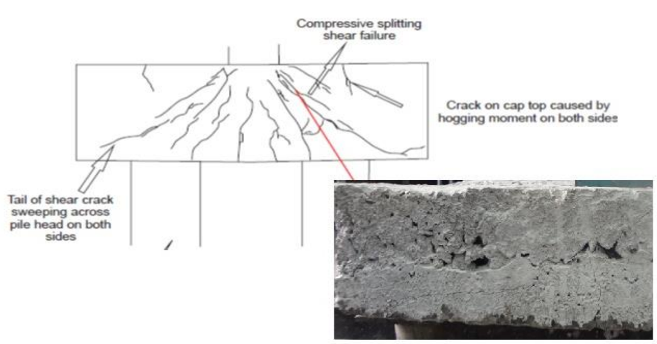


Figure-3 Crack distribution on PC-2B back surface at failure step

Take pile cap 1-A is front surface as an example (Figure-4). The front surface shows a standard crack distribution in a shear failure similar to a 1-way spanning of pile cap, *i.e.* the bending crack propagated a long way into the region under the vertical loading, and the critical compressive splitting crack developed linking the loaded area and the area above the pile head. The concrete near the tip of the shear crack was crushed. [3] The inclined compressive stress was expected to dominate in the inclined strut confined by the surrounding concrete.



Concrete being crushed under vertical loading

Figure-4 Front surface PC-1A

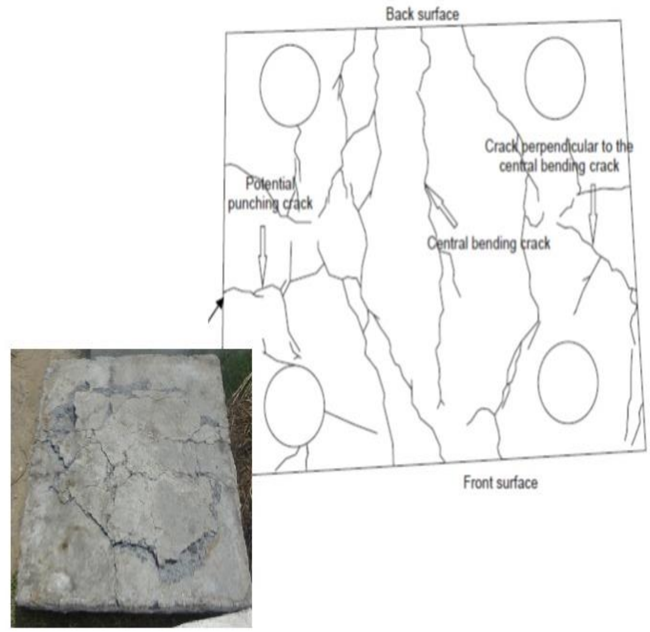


Figure-5 Crack distribution on PC-1A cap soffit at failure step

For experiment, as can be seen of the back surface of PC-1A and PC-2A, and the front surface of PC-1C (Figure-4, 5) caps failed in shear but with significant central bending cracks propagating widely and upwards deeply. On the other hand, the back surface of PC-3A (Figure-2) showed a bending failure with significant critical shear cracks.

Figure-6 Crack distribution on PC-1C cap soffit at failure step

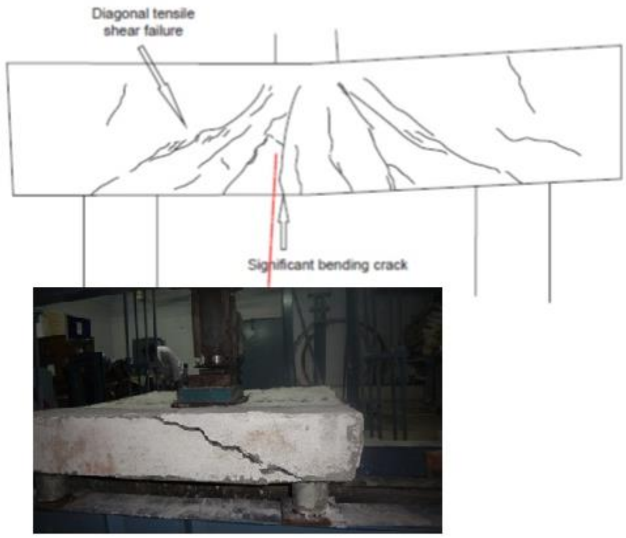


Figure-7 Crack distribution on PC-1B back surface at failure step

The crack distributions was that with the increasing pile transverse spacing, the cracking on the cap soffit became more 2-way, indicated mainly by the cracks occurring perpendicular to the main bending cracks on the soffit such as in PC-1B, PC-2C (Figure-7, 8) and PC-2B. This implied that the larger, the more possible that the reinforcement in the transverse direction took part in the shear resistance, and the bigger role the 2-way behavior of the cap and the behavior of an individual corner pile played relative to the normal shear behavior in a 1-way spanning beam.[4]

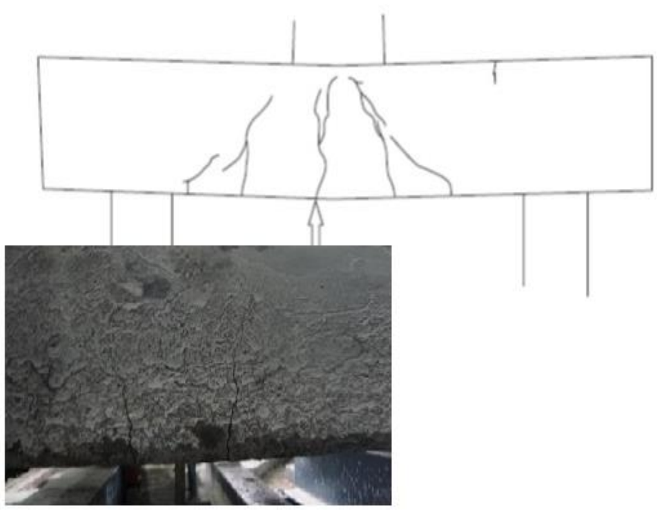


Figure-8 Crack distribution on PC-2C back surface at failure step

Compressive splitting shear cracks along the concrete strut usually initiated at the mid height of the cap and then propagated in both directions towards the pile head and the vertical loading e.g. on the front surface of PC-1A, PC-1C and back surface of PC-2A (Figure 4, 5, 6 and 9). A compressive splitting crack can also initiate because of crushing of the concrete immediately under the vertical loading, such as on the front and back surfaces of PC-2B (Figure-3) and front surface of PC-1B

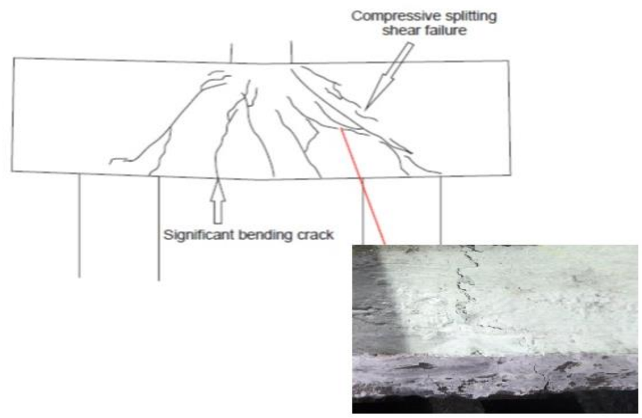


Figure-9 Crack distribution on PC-2A front surface at failure step

The bending crack and the critical shear crack matured rapidly one after the other with both opening widely, but one finally overwhelming the other. Apart from PC-1C (shear failure without any significant bending crack on front surface (Figure-6) and PC-3C (bending failure without any significant shear crack on back surface (Figure-10), bending failure and shear failure were always very close at the failure step.

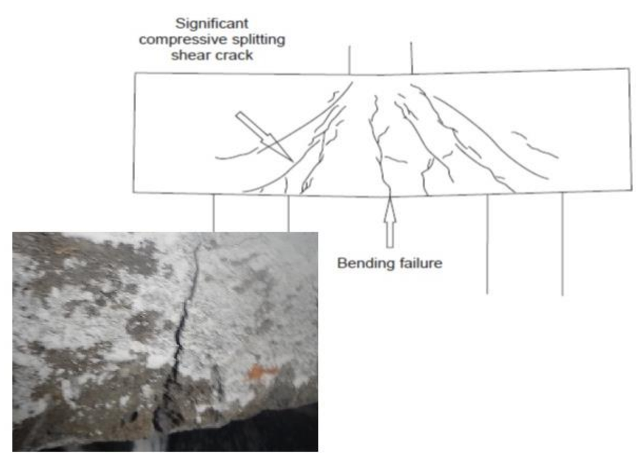


Figure-10 Crack distribution on PC-3C back surface at failure step

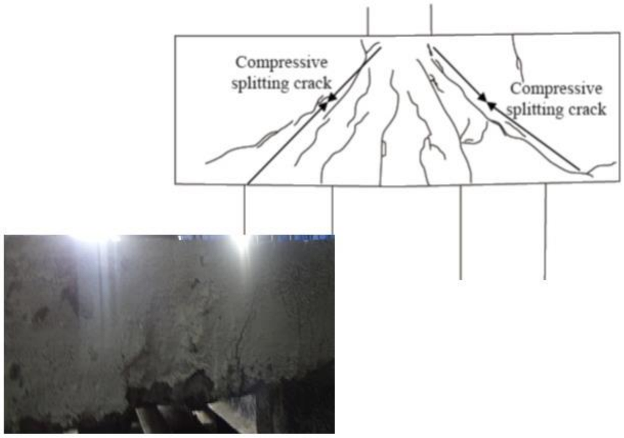


Figure-11 Crack distribution from experiment at the onset of the yield stage

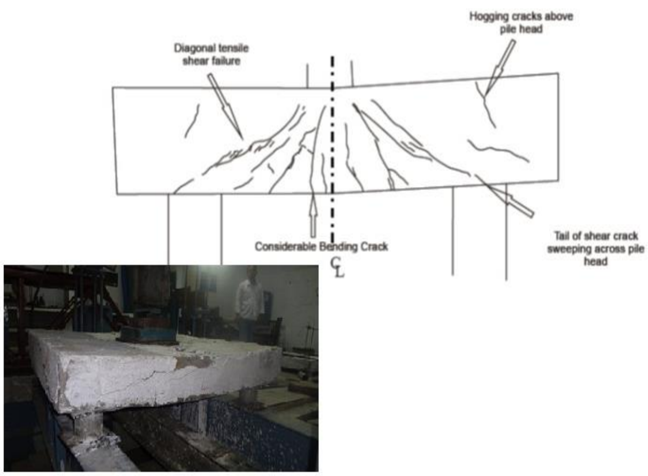


Figure-10 Observed crack pattern

Failure load – 205 KN PC-1A

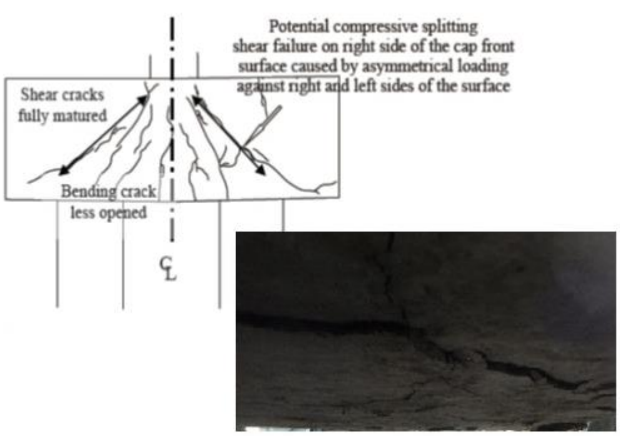


Figure-12 Observed crack pattern in experiment

Conclusion

So far, all results have been for pile caps subject to the vertical loading. It is expected that the shear capacity and mechanism may vary with the load pattern, and so in order to study its crack pattern the shear behaviors of pile cap experimental samples under a concentrated vertical load, and a model in the parametric study under a vertical loading with depth increased were investigated. The design of three batch samples, and testing of pile cap at study and the behavior of shear failure, punching failure and crack pattern at concrete cap. It is clear from the above discussion that the failure mechanism of pile cap under the vertical loading with reduced depth is neither the punching shear failure as under concentrated load.

Reference

1. Indian standard code of practice for design and construction of pile foundations bureau of indian standards IS 2911-1979 and IS 2911-1984.

2. Code of practice for road and bridges of indian road congress IRC 112-2011.

3. Indian standard code of practice for design and construction of pile foundation bureau of indian standard IS 2911 part-4 1985.

4. Reinforced concrete design of pile cap BS 8110.

5. British standard code of practice and design for foundation BS 8004-1986 (formerly CP-2004).

6. Indian standard code of practice. (1979). "Design and construction of pile foundation, IS 2911 (part 1/sec. 3)." New Delhi, India.

7. ACI Committee 445 (1998). "ACI Committee 445 on Shear and Torsion Recent Approaches to Shear Design of Structural Concrete." *Journal of Structural Engineering ASCE*, 1375-1417.

8. Adebar, P., Kuchma, D., and Collins, M. P. (1990). "Strut-and-tie Models for the Design of Pile Caps: an Experimental Study." *ACI Structural Journal*, 87(1), 81-92.

9. Adebar, P., and Zhou, L. (1996). "Design of Deep Pile Caps by Strut-and-Tie Models." *ACI Structural Journal*, 93(1), 56-64.

10. Ashour, A. F. (2000). "Shear Capacity of Reinforced Concrete Deep Beams." *Journal of Structural Engineering ASCE*, 1045-1052.

11. Ashour, A. F., and Morley, C. T. (1994). "The Numerical Determination of Shear Failure Mechanisms in Reinforced-concrete Beams." *The Structural Engineer*, 72(24), 395- 400.

12. Ashour, A. F., and Morley, C. T. (1996). "Effectiveness Factor of Concrete in Continuous Deep Beams." *Journal of Structural Engineering ASCE*, 169-178.

13. Bazant, Z. P. (1983). "Crack Band Theory for Fracture of Concrete." *Materials et Constructions*, 16, 155-177.