Design and Construction Considerations for Prestressed Concrete Structures

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With the increasing use of prestressed concrete in buildings, this article is timely. Most consultant engineers are not familiar with prestressed concrete design and are happy to leave it to the specialists. But more knowledge about prestressed concrete can go a long way towards ensuring that the owner's interests are properly safeguarded if problems do crop up. The following considerations should be looked into when opting for a prestressed solution.

RESTRAINING WALLS

Adverse effects of restraining walls should be taken into account when prestressing is applied. Members under compression due to prestressing will contract and, if prevented by stiff walls, tend to crack especially when such walls are located towards the two ends where stressing takes place Figure1 (1). Favourably placed walls located towards middle of building as in Figure 2 (1) will not interfere with the free contraction of prestressed members. Otherwise most of the prestress will end up in the walls rather than the members they are supposed to precompress. Figure 3 (1) shows crack pattern in prestressed slab in a building with shear walls unfavourably positioned.

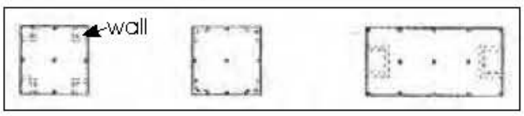

Figure 1: Unfavourable arrangement of restraining walls

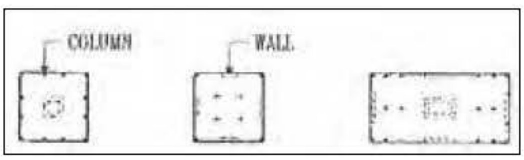

Figure 2: Favourable arrangement of restraining walls

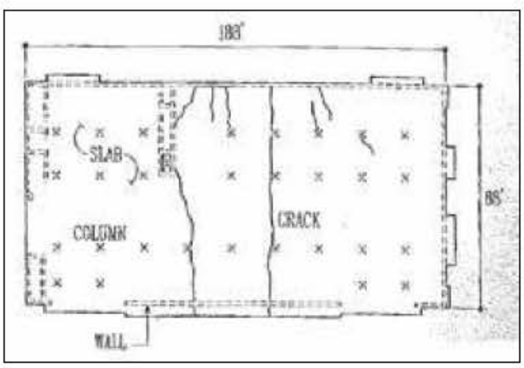

Figure 3: Crack pattern for prestressed slab with unfavourably placed walls

BASEMENT WALLS

Where basement walls are present, slabs and beams should not be prestressed (2) without taking into account the stiffness of the walls. As such, walls are relatively stiff compared to the flexural members. They tend to attract most of the the prestressing force and distress will show up later in the flexural members which end up with only a fraction of the intended design prestress.

POUR STRIPS

However if unfavourable location of shear and basement walls is inevitable, then the judicious placement of pour strips Figures 4 & 5 may overcome the abovementioned diversion of prestress to the stiffer walls. Pour strips are gaps left between two regions of prestressed slabs which are concreted after contraction due to prestressing and preliminary drying shrinkage has taken place.

If pour strips are not provided, then more prestressing will be required where restraining shear walls are countering the effective prestressing of the slab Figure 6 (1). For such cases, a certain amount of previous experience will prove invaluable when deciding how much more to provide.

OPENINGS IN PRESTRESSED SLAB

Openings in prestressed slabs are areas of discontinuity which are prone to cracking. Figure 7 (1) shows that terminating all tendons at the edges of the opening will promote cracking whereas overlapping of tendons will help to inhibit cracking.

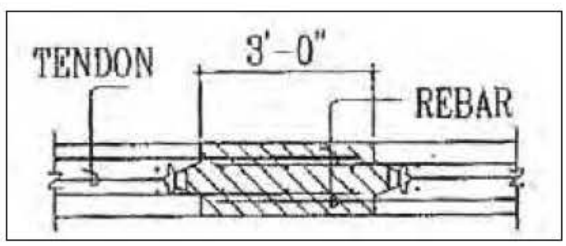

Figure 4: Pour strip

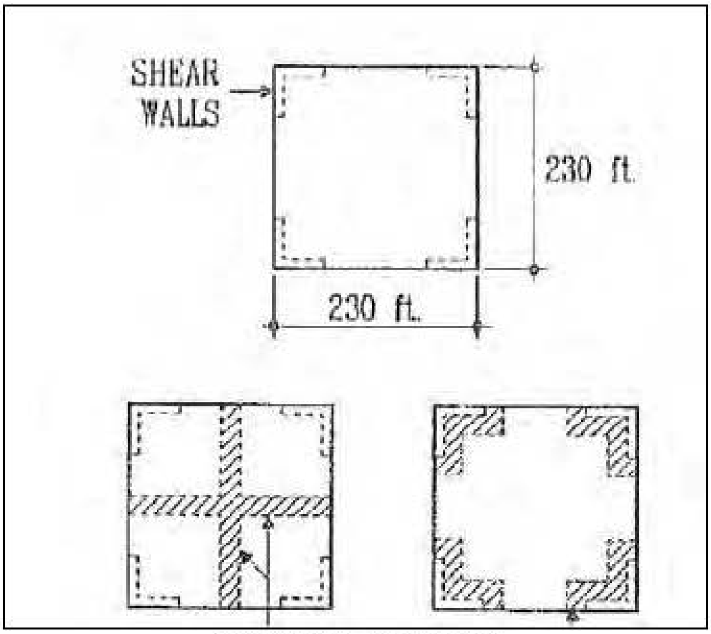

Figure 5: Placement of pour strips

OPENINGS IN PRESTRESSED BEAMS

Although openings in prestressed beams are not recommended, there are times when this cannot be avoided. Currently, openings in reinforced concrete beams are well researched (3), (4) , (5) and published investigations into openings in prestressed beams are comparatively scarce (6), (7). Abdalla *et al.*, (5), (6) have proposed a method for checking the strength of prestressed beams with openings which are modified from that proposed for reinforced concrete beams (4) (5) by taking the effect of prestressing into account. A simpler method however is desirable as this method can be rather time consuming. Currently the authors are working on a quicker approach to this problem.

PRESTRESSED BEAMS ON CORBELS

There is a need to consider horizontal forces and possible movement of bearing pad as continuous contraction is expected due to prestressing and shrinkage effects. Design of reinforced concrete corbels is a straightforward thing (8) but for prestressed beams, shortening of the beam and horizontal forces due to contraction need to be estimated and taken into account in the design. Improper positioning of the bearing pad may be exacerbated by contraction and will result in spalling of concrete cover at the face of corbel in many instances.

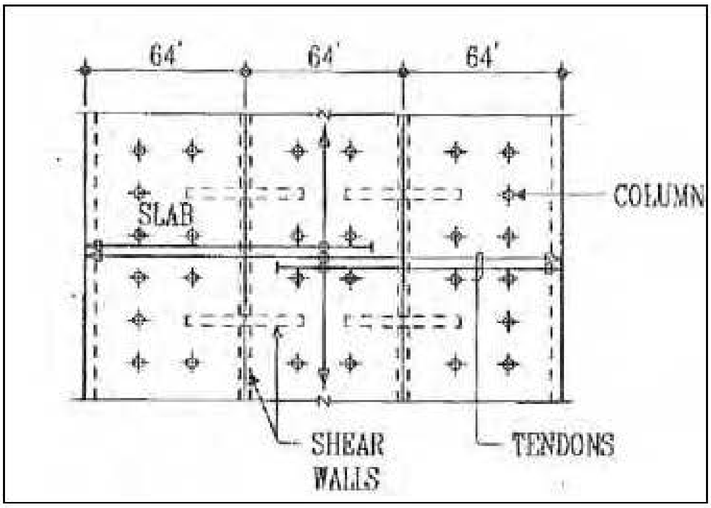

Figure 6

GROUND SLABS

Prestressing of ground slab and beams needs to be carefully evaluated as the restraining effect of the ground, pile caps or even piles need to be evaluated. Indiscriminate application of prestressing may lead to much of the prestressing ending up in members other than those intended Figure 7.

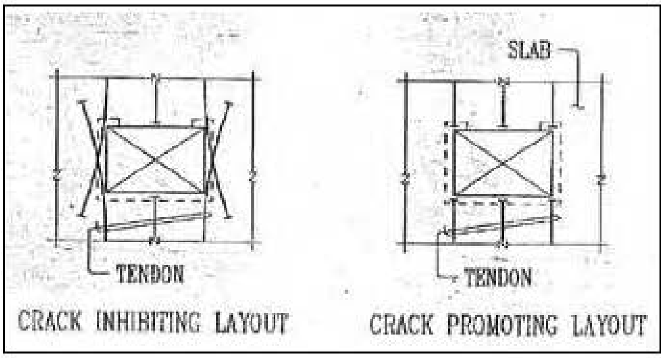

Figure 7

STAGE STRESSING

This is normally required for transfer beams. Depending on the number of storeys supported, the transfer beam needs to be stressed in stages and definitely more than once. Of course it costs less to do it fewer times. But in doing so, take great care and ensure accuracy in estimating the actual building loads. It is a misconception that overestimating the building loads will result in a "safer" design. This may be true for reinforced concrete buildings but it's not necessarily true for prestressed buildings as a greater load may require a higher prestressing force which, if carried out, can cause cracking if not countered in actuality by the expected heavier load.

CURVED PRESTRESSED BEAMS

Beams curved on plan are susceptible to torsion from prestressing as the tendon in the beam will apply an eccentric radial force about beam's centroid, giving rise to torsional moments which, if ignored, have been known to cause beam failure in certain instances.

MEASUREMENT OF TENDON ELONGATION DURING STRESSING

The importance of this activity in the construction of prestressed beams

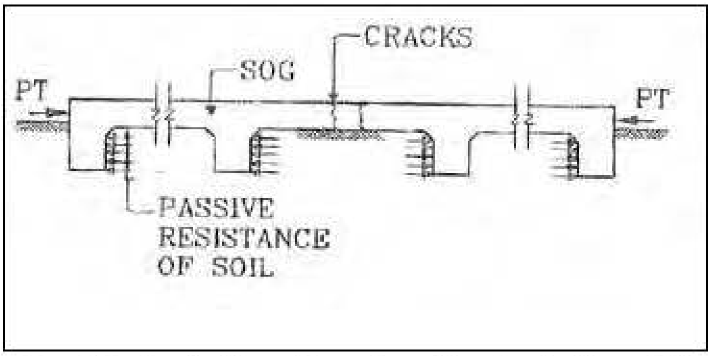

Figure 8: Cracks arising from resistance of ground to prestressing of ground slab

cannot be overstressed. Accurate measurement of tendon elongation and comparison with predictions are crucial in determining if stressing has been carried out properly and that everything is going according to plan. Any discrepancy can be attributed to a variety of reasons: Faulty jacks, breakage of tendons, leakage of grout into ducting, overstressing and understressing. Such occurrences need to be fully and thoroughly investigated till a satisfactory explanation is obtained. Otherwise it may spell disaster.

CONCLUSION

The above factors affecting design of prestressed beams are not comprehensive or exhaustive. What we hope for is that it will lead to more articles. The exchange and sharing of information/knowledge in this area is always considered the exclusive purview of specialists. ■

REFERENCES

[1] Aalami and Barth, "Cracking in prestressed concrete" SP113, ACI, 1989.

[2] Siao WB, "Design of the Singapore Treasury Building", IEM Bulletin, 1989, September.

[3] Siao WB; Yap, S.F., "Ultimate behaviour pp51-58 of unstrengthened large openings in existing beams," IES Journal, Singapore, V3, No.3, May-June 1990

[4] M.A. Mansur; Y.F. Lee; K.H. Tan; S.L. Lee, "Tests on rc continuous beams with openings", ASCE *Journal of Structural Engineering*, Vol.117, No. 6, June, 1991.

[5] M.A. Mansur; K.H. Tan; Y.F. Lee; S.L. Lee, Piecewise linear behavior of rc beams with openings ASCE *Journal of Structural Engineering*, Vol. 117, No. 6, June, 1991

[6] John B. Kennedy; Hany Abdalla, "Static response of prestressed girders with openings", ASCE *Journal of Structural Engineering*, Vol. 118, No. 2, February,1992.

[7] Hany Abdalla; John B. Kennedy "Design of prestressed concrete beams with openings", ASCE *Journal of Structural Engineering*, Vol.121. No.5. May. 1995.

[8] Siao, W.B, "Shear strength of short RC walls, deep beams and corbels," ACI Structural Journal , Vol. 91, No.2, Mar-April 1994, pp123-132