Discussion: Experimental research on plastic design method and moment redistribution in continuous beams prestressed with unbonded tendons

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Contribution by Bernard Espion

The purpose of the paper by Zhou and Zheng (2010) is to report and analyse the results of the testing up to failure of continuous beams prestressed with unbonded tendons. The writer finds that several important data that are necessary fully to understand and exploit the results are lacking. It is quite impossible to validate and use their results independently if the authors do not provide the experimental values of the ultimate loads, the value of the effective stress in the tendons σ_{pe} used in their computations, the value of σ_{con} (which is not exactly defined) and the actual value of the yield force of the bonded reinforcement in each critical section of each beam. Is the effective depth of the bonded reinforcement in the critical sections the same as h_p , the effective depth of the tendons? Using non-dimensional ratios or indices only is in fact not sufficient to model the beams tested by the authors.

Additionally, a very important factor for the analysis and design of beams and slabs prestressed with unbonded tendons, whether continuous or not, is the stress increase in the tendons at ultimate $\Delta\sigma_p$. The authors mention that they have measured the force in the tendons during their tests but they do not report any experimental value; if provided with the above-mentioned missing data; this information would turn the results of the authors into a very valuable addition to the data bank of already existing test results up to failure on continuous systems post-tensioned with unbonded tendons. As rightly pointed out by the authors, the number of experimental research efforts in the field is limited. However, the writer wonders why they have mentioned several research efforts or studies dealing with continuous systems prestressed with bonded tendons but hardly any on continuous beams or one-way slabs post-tensioned with unbonded tendons that are reported in the literature.

The writer would like also to comment on a more general level on the issues of redistribution and plastic design in statically indeterminate prestressed concrete systems because this is still a

problem that is not fully understood and satisfactorily handled in design codes. It is first necessary to define the meaning of words properly. The behaviour of any concrete continuous system in a testing up to failure will depart from linearity (or, to use the words of the authors, from the elastic distribution) as soon as cracking begins. Above that loading level, the ‘redistribution’ of bending moments between the critical sections (i.e. departure from the linear distribution) is governed by the relative stiffnesses of the critical sections. The only interesting questions concerning the applicability of a true plastic method (words used by the authors in their title) are: are the critical sections sufficiently ductile to allow a full redistribution of the bending moments at failure? If this is the case, it means that the so-called secondary moment (which are elastically determined) vanish at ultimate and that the distribution of acting (actual) bending moments gently coincides at ultimate with the distribution of ultimate resisting bending moments. Then, the carrying capacity may be very simply computed from the application of either one of the theorems (lower bound or upper bound) of the limit load (plastic) analysis. Unfortunately, the authors do not provide sufficient information concerning what really happens at failure in their tests: does the actual distribution of the acting bending moment match the distribution of ultimate resisting moments that can be computed beforehand from section properties? How would a simple plastic estimation of the carrying capacity approximate the measured values of the experimental ultimate loads? It is highly probable that such an approach would be accurate enough for their beams with low and intermediate reinforcement indexes.

Finally, the writer would like to mention that the final editing of the paper still includes a series of errors: for instance, there is an inconsistent use of M_u^t , M_u^e and M_u^c in the Notation section, in the core of the text p. 58, in Equation 1 and in Table 4. A unit should be given to the abscissa of Figure 11, because the parameter $k_1(\theta_p/h_0)$ has the dimension of the inverse of a length.

Authors' reply

The main purpose of the paper is to investigate the degree of moment redistribution of continuous unbonded prestressed concrete beams. Therefore, the experimental results of 16 unbonded prestressed concrete beams were analysed. Some basic parameters were indicated in the tables of the main text, such as the global reinforcement index, the prestressing reinforcement index, the tension non-prestressing reinforcement index and the compression non-prestressing reinforcement index. Under the condition of the known dimension of tested beams, the mean compressive strength of concrete, the areas of longitudinal steel including prestressing wire and non-prestressing rebar and the effective depth of prestressing tendons, the other parameters such as the effective stress in the tendons σ_{pe} , and the yield strength of non-prestressing steel have been covered in those fundamental parameters. In main text, the other parameters can be calculated on basis of the definition of fundamental parameters and Table 1. As three actual support reactions can be measured by a support sensor, combined with the span values of the beams, the actual moment in critical sections of the tested beams was determined and shown in Table 4. Thus, the experimental values of the ultimate loads of 16 tested beams were also indirectly shown in Table 4. The effective depth of the prestressing tendons of the critical section of the tested beams was shown in Table 3. The effective depth of the non-stressing steel in the critical section is different with tendons. This can be gained by the depth of beam subtracting concrete coat thickness 25 mm. Therefore, the fundamental parameters (non-dimensional indices) can contain much useful information, and clearly simply express the behaviour of continuous concrete beams prestressed with unbonded tendons.

Second, the stress increase in unbonded tendons up to failure has been measured, and the data have been collected for tested beams including ultimate stress of unbonded tendons. As the important significance of stress increases, the relative data and research results will be analysed in another paper. For the purpose of redistribution of continuous beams, many efforts of bonded prestressed continuous beams or one-way slabs have been completed in literature; however, little research on the redistribution of unbonded prestressed continuous beams or one-way slabs has been reported in literature.

Finally, as prestressing equivalent loads can be treated as an external load, the sum of the ultimate elastic bending moment with secondary bending moment owing to prestressing should be redistributed as the variable, and thus the same degree of bending moment redistribution at the critical section over the inner support should be used in the ultimate elastic bending moment and secondary bending moment. Therefore, it is never considered that the secondary moment will vanish at the ultimate state. In the main text (p. 58), the negative bending moment at the section over support M_u^e including the secondary moment is adjusted by the degree of redistribution. The unit of the parameter $k_1(\theta_p/h_0)$ is the reciprocal of length.

REFERENCE

Zhou W and Zheng WZ (2010) Experimental research on plastic design method and moment redistribution in continuous concrete beams prestressed with unbonded tendons. *Magazine of Concrete Research* **62**(1): 51–64, doi: 10.1680/mac.2008.62.1.51.