DESIGN OF NON-PRESTRESSED MEMBERS OF STRUCTURES THAT INCLUDE PRESTERSSING ELEMENTS[1]

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This Technical Note deals with the design of members in structures that include both prestressed and non-prestressed parts. The structure shown in Fig. 1 is used to illustrate the procedure. In this structure member BC is post-tensioned, but the remainder are not. The objective of the narrative is to explain the design of members such as AB and AF, recognizing that their performance is impacted by the presence of prestressing (PT) in member BC.

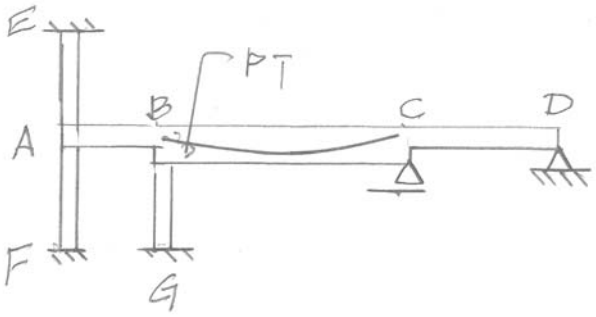

FIGURE 1 VIEW OF HYPRID STRUCTURE WITH BOTH PRESTRESSED AND CONVENTIONALLY REINFORCED MEMEBRS

Members that are not prestressed, such as AB and AF are treated following the common procedure for conventionally reinforced structures. The stress check that is generally carried out for prestressed members, such as BC in Fig. 1 does not apply to conventionally reinforced parts of the structure, such as member AB.

The impact of prestressing on the non-prestressed members is at ultimate limit state (ULS) used for safety check and in deflections. All major building codes consider the impact of prestressing on strength demand of a member through the actions (moment, shear, axial) that the prestressing generates in them. These actions are referred to as “hyperstatic” actions and enter the load combination for strength evaluation with factor 1. For example, using the IBC-2009 code one load combination for the strength evaluation of member AB and AF is:

$$1.20DL + 1.60LL + 1.00HYP \qquad (1)$$

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Where DL, LL, and HYP are respectively dead, live and hyperstatic values. Prestressing is the source of hyperstatic actions. This load combination applies to both prestressed and non-prestressed members of a structure, where any part of the structure includes prestressing.

Conventional procedures are used to determine the actions from dead and live loads. The focus of this narrative is the determination of hyperstatic values that are to be added to the strength load combination. Two options are generally used, namely “Extended Load Balancing,” and “Hyperstatic Reactions.”

EXTENDED LOAD BALANCING

In this procedure the prestressing tendons are replaced by (i) lateral forces that they exert to their housing, shown as Wb in Fig. 2 and (ii) the concentrated forces at the anchorages, shown as P in the same figure. The lateral forces in most instances are in the up and down directions. The concentrated forces at the anchorages do not necessarily align and neutralize one another. For a correct and reliable design, it is critical to ensure that the combined forces of the extended balanced loads (Wb and P) are in static equilibrium, irrespective of the geometry of the structure they are being applied to.

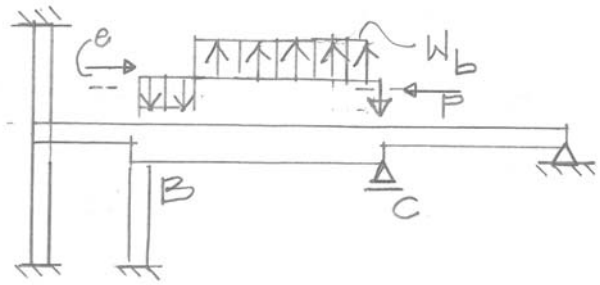

FIGURE 2 SUBSTITUTION OF PRESTRESSING BY EXTENDED BALANCED LOADS

The entire structure is analyzed under the action of “extended balanced loads.” The solution obtained is the hyperstatic action (HYP) due to prestressing for NON-PRESTRESSED members only, and can be used directly in strength load combinations such as relationship 1. The prestressed members, such as member BC are designed using procedures applicable to them and discussed elsewhere.

HYPERSTATIC REACTIONS

In this procedure, the reactions at the support boundaries of the structure, such as points E and F that are obtained either from the outcome of the design of the prestressed member (Fig. 1) or the extended balanced loads (Fig. 2) are extracted and applied to the structure as external loads (Fig. 3). Since the reactions are in static equilibrium, the structure detached from its supports (Fig. 3) will be stable and will yield a solution. The solution obtained (moments, shears, etc) represents the hyperstatic actions from prestressing and can be used directly in the ultimate load combination for design. It is important to note that, unlike the previous approach, in this case the values APPLY UNIVERSALLY TO ALL MEMBERS of the structure, irrespective of whether a member does or does not contain prestressing.

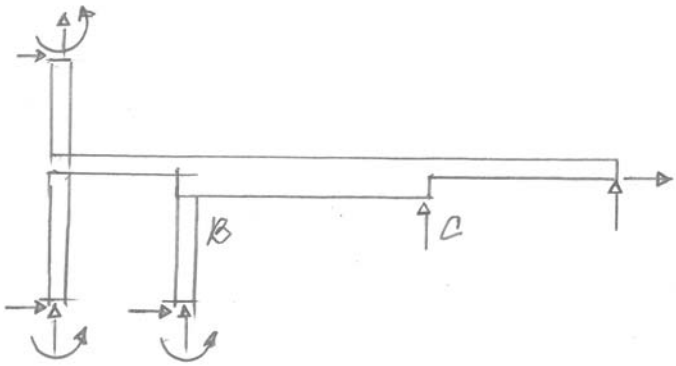

FIGURE 3 SUSBTITUTION OF THE EFFECTS OF PRESGTRESSING THROUGH HYPERSTATIC REACTIONS

The formulation of the computer program ADAPT-Floor Pro is based on this procedure. The program reports the hyperstatic actions applicable to both prestressed and non-prestressed members of a structure. Hence, where Floor Pro program is used, the same load combination is applicable to both prestressed and non-prestressed members to determine the design values (demand values). In its design procedure, the program recognizes the presence of prestressing, where available, and accounts for it as a resisting element.