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The use of partial blanketed strands in design of prestressed precast beams

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Abstract. Concrete is considered to be prestressed when it is subjected to a state of strain and deformation before being loaded with payloads from service stage. Efforts and deformations resulted from prestress are so established to counteract the effects produced by the transfer and service loads. Efficient design of prestressed precast beams is based on the rational use of materials: concrete and reinforcement (especially strands). Poor use of materials in design phase may result in inappropriate solutions from an economic point of view. To avoid this aspect partial blanketed strands are used. To obtain a partial blanketed strand the adhesion between it and concrete is stopped punctually, the transfer of tensions being carried out in the contact areas. In the present paper it will be illustrated the stress development on the beam resulting from the use of partial blanketed strands. To highlight these particularities the IDEA StatiCA software was used and, the results presented graphically and tabular revealed the advantages of partial blanketed strands.

1. Introduction

Partial blanketing the prestressed strands towards the ends of a beam reduces the shear strength of the sections in regions where imposed shear forces are the highest. This reduction in shear strength of the members applies to all sections, weather cracked or uncracked in flexure. Partial blanketing is effective for the design of simply supported beams because of the consequent reduction of prestress in the support area, being able to provide significant less compressive stress in the top fibres of the beams and provide the same bearing capacity.

Blanketing (debonding) can be achieved by greasing the strand, coating it with retarder, or covering it with plastic tubing. Greasing or using a retarder is risky because of the possibility of affecting other than the specified strands. Plastic tubing is preferred because it also provides an easy mean of inspection. Traditional soft sheathing is not producing the desired debonding effect due to the lack of rigidity. The rigid polymer proved to an effective way to create more clearance between steel and concrete ensuring a debonding behaviour.

2. Blanketing principles

For the proper usage of partially blanketed strands methodology is necessary to establish the number of debonded strands, the debonded length and the release pattern in correlation with the basic requirements of limiting the tensile stresses in the concrete at the top fibres at transfer and the ability to satisfy the checks imposed by the ultimate limit state and the serviceability limit state. At this point are not established specific rules for applying the partial blanketing methodology, only some general guidelines existing.

Excessive debonding may result in a negative impact upon the structural performance of prestressed precast concrete beams by producing cracking at the extremity during the strands release stage of the production process.



The general guidelines regarding using partial blanketed strands are presented next:

- the development length is measured from the end of debonded zone;
- the length of debonding zone of any strand shall satisfy limit state with consideration of total developed resistance at any section;
- the exterior strands of each horizontal row shall be fully bonded;
- not more than 25% of the total strands can be debonded;
- no more than 40% of the debonded strands, or four strands, whichever is greater, shall have the debonding terminated at any cross-section;
- not more than 40% of the strands at any one horizontal row will be debonded;
- symmetric debonding about member cross-section centreline is required;
- strands in the corners of stirrups preferably should not be debonded;
- adjoining strands form a layer of strands should not normally be debonded at the same section;
- debonded length of pairs of strands that are symmetrical positioned about the centreline of the member shall be equal;
- shear investigation shall be made in the regard to the reduce horizontal force.

3. Experimental phase

To illustrate the mechanisms that appear by using partial blanketed strands when designing precast prestressed concrete beams, a study was carried out on a number of 25 beams. The IDEA StatiCA software was used to accomplish the simulations.

Given that the design of precast prestressed concrete beams is a meticulous task it was necessary for a number of conventions to be made. By imposing a certain number of parameters to be fixed, we can focus only for the principal parameters that are correlated with the blanketing methodology.

In the Section 3.1. are detailed the fixed parameters and in Section 3.2. are detailed the variable parameters.

3.1. Fixed parameters

From this category the follow parameters are fixed:

- beams length: 25.5 m, static scheme, sections as is showed in figure 1 and figure 2;

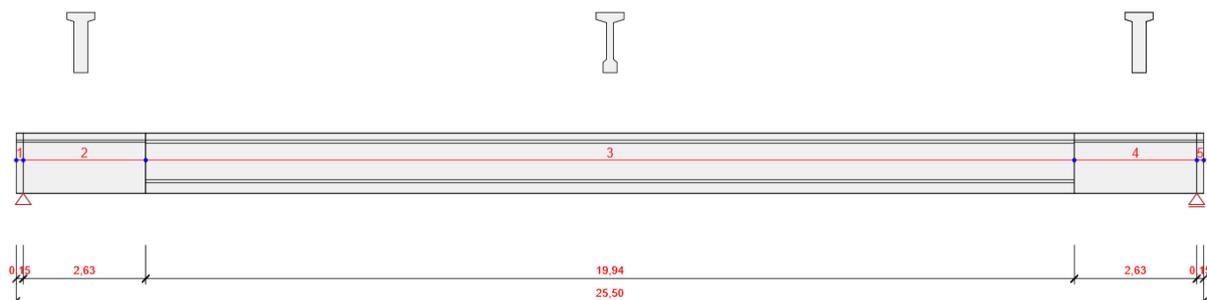


Figure 1. Static scheme

- concrete strength class (according to Eurocode 2): C50/60;
- strands used: Y1860S7-15.2;
- strands layout (a total of 16 strands being positioned in a number of 8 groups composed of 2 strands as it shown in figure 3 and figure 4);
- initial tensile stress in strands: 1100.0 MPa;
- passive reinforcement: steel grade (B500C), layout of passive reinforcement;
- load cases (self-weight, permanent load: 9.1 kN/m, variable load: 15.4 kN/m, load per construction stage G 5: 1.0 kN/m).

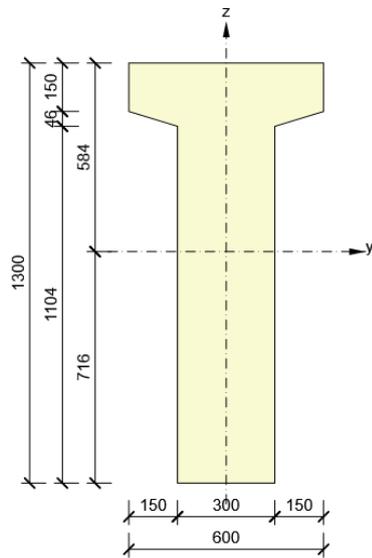


Figure 2. Section 1 as is showed in figure 1 (cm)

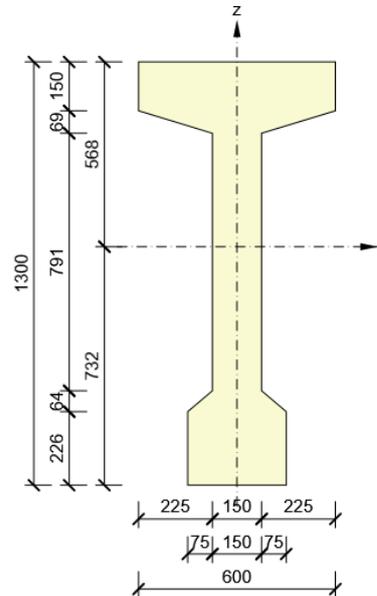


Figure 3. Section 2 as is showed in figure 1 (cm)

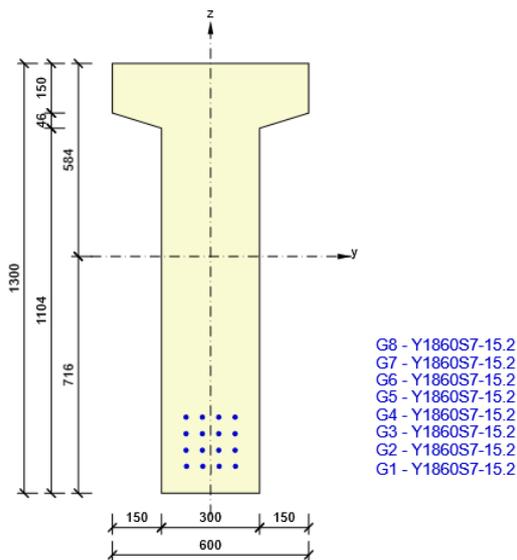


Figure 4. Strands layout in Section 1

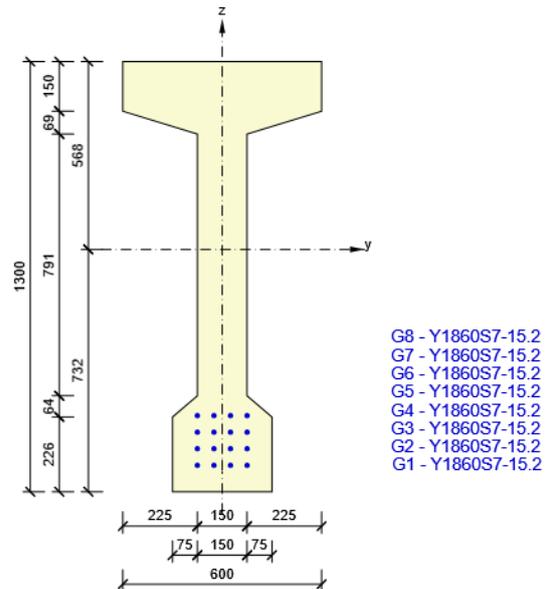


Figure 5. Strands layout in Section 2

3.2. Variable parameters

As it was stated before a study was carried out a number of 25 beams, the only parameters being alter were the positions of debonded strands and their debonded length.

To better understand how the strands groups were considered their positions were illustrated in the cross sections of the beams. The debonded length was presented in tables 1 to 7 for each beam and depending on the strands group.

Beam G 1.0.0 is the reference beam (all strands are bonded), and it will serve to highlight the difference resulted from using partial blanketed strands.

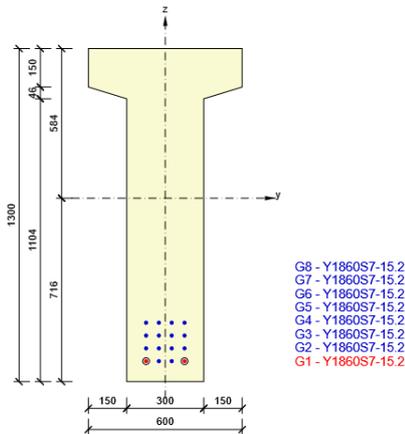


Figure 6. Debonded strands in beams G 1.1.1, G 1.1.2, G 1.1.3

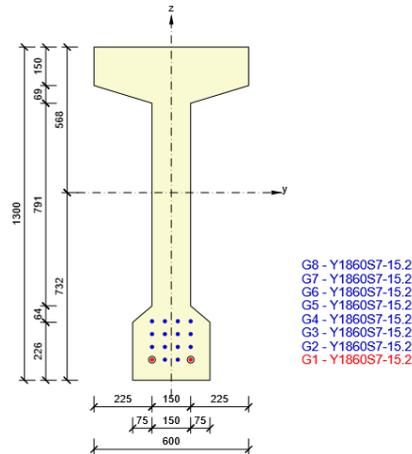


Figure 7. Debonded strands in beam G 1.1.3

Table 1. Debonding lengths (m) / strands group for beams G 1.1.1, G 1.1.2, G 1.1.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.1.1	2.50	-	-	-	-	-	-	-
G 1.1.2	2.75	-	-	-	-	-	-	-
G 1.1.3	3.00	-	-	-	-	-	-	-

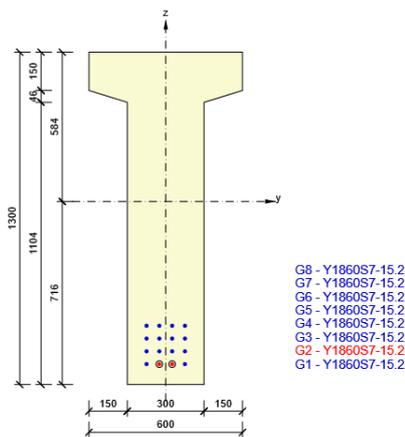


Figure 8. Debonded strands in beams G 1.2.1, G 1.2.2, G 1.2.3

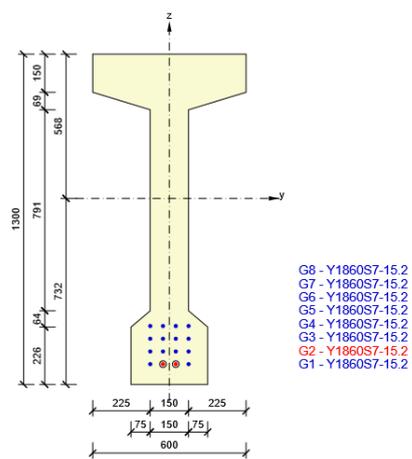


Figure 9. Debonded strands in beam G 1.2.3

Table 2. Debonding lengths (m) / strands group for beams G 1.2.1, G 1.2.2, G 1.2.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.2.1	-	2.50	-	-	-	-	-	-
G 1.2.2	-	2.75	-	-	-	-	-	-
G 1.2.3	-	3.00	-	-	-	-	-	-

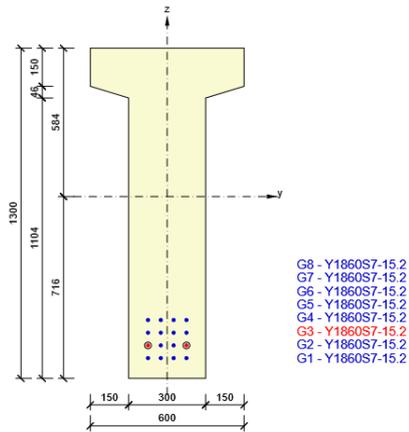


Figure 10. Debonded strands in beams G 1.3.1, G 1.3.2, G 1.3.3

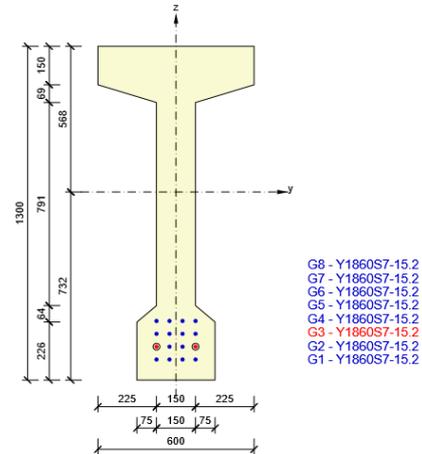


Figure 11. Debonded strands in beam G 1.3.3

Table 3. Debonding lengths (m) / strands group for beams G 1.3.1, G 1.3.2, G 1.3.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.3.1	-	-	2.50	-	-	-	-	-
G 1.3.2	-	-	2.75	-	-	-	-	-
G 1.3.3	-	-	3.00	-	-	-	-	-

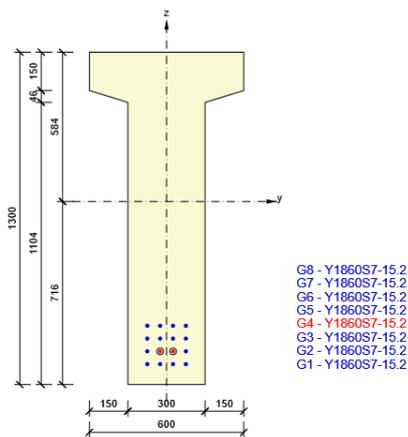


Figure 12. Debonded strands in beams G 1.4.1, G 1.4.2, G 1.4.3

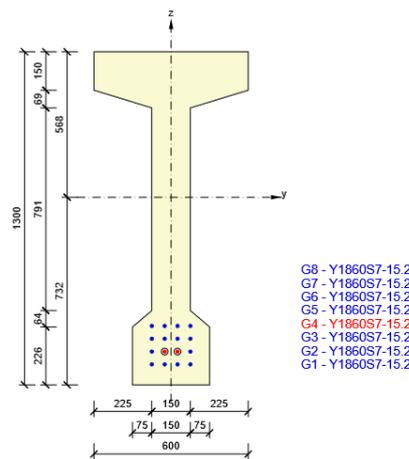


Figure 13. Debonded strands in beam G 1.4.3

Table 4. Debonding lengths (m) / strands group for beams G 1.4.1, G 1.4.2, G 1.4.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.4.1	-	-	-	2.50	-	-	-	-
G 1.4.2	-	-	-	2.75	-	-	-	-
G 1.4.3	-	-	-	3.00	-	-	-	-

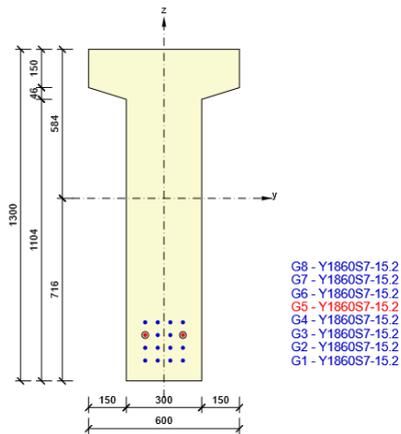


Figure 14. Debonded strands in beams G 1.5.1, G 1.5.2, G 1.5.3

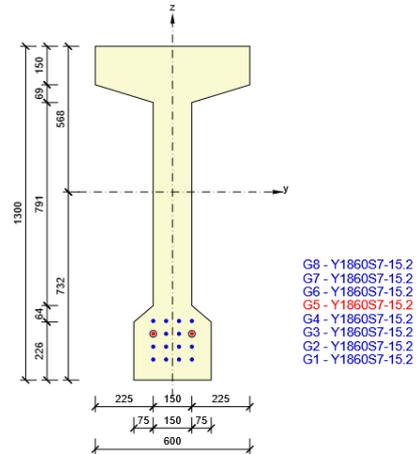


Figure 15. Debonded strands in beam G 1.5.3

Table 5. Debonding lengths (m) / strands group for beams G 1.5.1, G 1.5.2, G 1.5.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.5.1	-	-	-	-	2.50	-	-	-
G 1.5.2	-	-	-	-	2.75	-	-	-
G 1.5.3	-	-	-	-	3.00	-	-	-

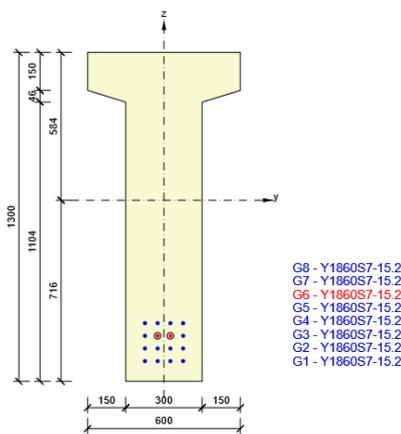


Figure 16. Debonded strands in beams G 1.6.1, G 1.6.2, G 1.6.3

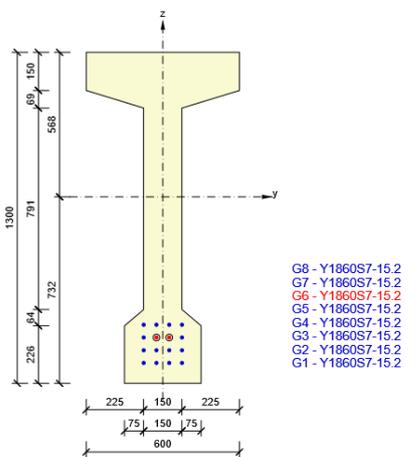


Figure 17. Debonded strands in beam G 1.6.3

Table 6. Debonding lengths (m) / strands group for beams G 1.6.1, G 1.6.2, G 1.6.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.6.1	-	-	-	-	-	2.50	-	-
G 1.6.2	-	-	-	-	-	2.75	-	-
G 1.6.3	-	-	-	-	-	3.00	-	-

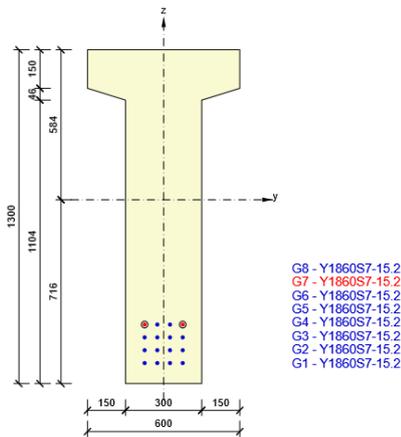


Figure 18. Debonded strands in beams G 1.7.1, G 1.7.2, G 1.7.3

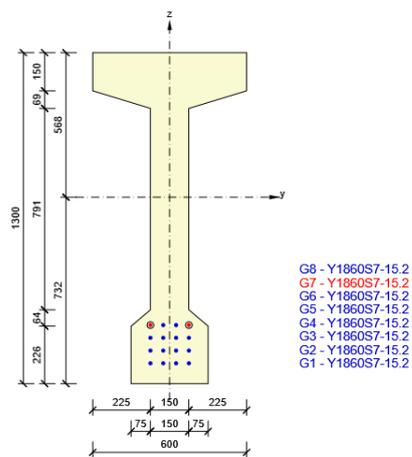


Figure 19. Debonded strands in beam G 1.7.3

Table 7. Debonding lengths (m) / strands group for beams G 1.7.1, G 1.7.2, G 1.7.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.7.1	-	-	-	-	-	-	2.50	-
G 1.7.2	-	-	-	-	-	-	2.75	-
G 1.7.3	-	-	-	-	-	-	3.00	-

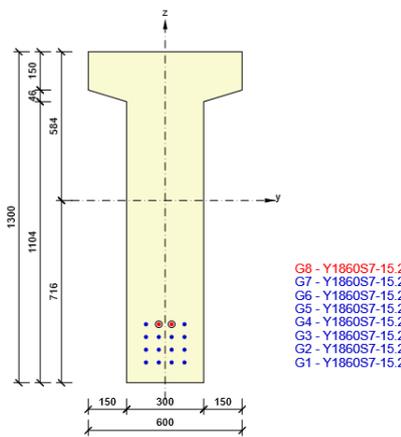


Figure 20. Debonded strands in beams G 1.8.1, G 1.8.2, G 1.8.3

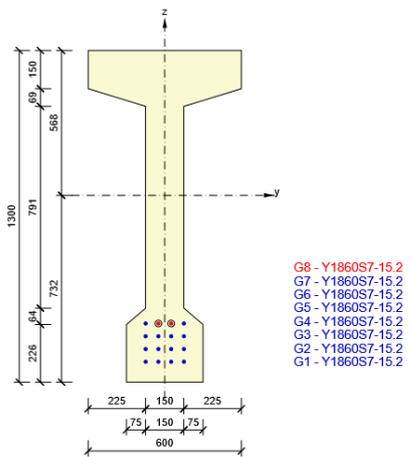


Figure 21. Debonded strands in beam G 1.8.3

Table 8. Debonding lengths (m) / strands group for beams G 1.8.1, G 1.8.2, G 1.8.3

Beam	Strands group							
	G1	G2	G3	G4	G5	G6	G7	G8
G 1.8.1	-	-	-	-	-	-	-	2.50
G 1.8.2	-	-	-	-	-	-	-	2.75
G 1.8.3	-	-	-	-	-	-	-	3.00

3.3. Results

Due to the high volume of simulations the results are presented graphically. To simplify the results presentation only the eloquent comparisons are part of this paper.

In the current section are presented the following:

- maximum tensions in the strands after stress transfer due to the different layout of debonded strands;
- maximum tensions in the strands after stress transfer due to the different debonded length;
- the bending moment (M_y) in the support area of the beams in the top fibers (envelope);

All 25 beam analysed meet the requirements of EUROCODE 2.

The figure 22 described the tensions development in the strands related to the reference beam (G 1.0.0). The stress losses in strands are decreasing from the strands situated near of the extreme fiber to those situated closer to the y-y axis of the beam. It can be notice that the strands situated at the same row have the same stress losses. The maximum stress after transfer is achieved in strands group G7 and G8 with a value of 1001.2 MPa, while the lowest stress after transfer is obtained in strands group G1 and G2 with a value of 992.3 MPa.

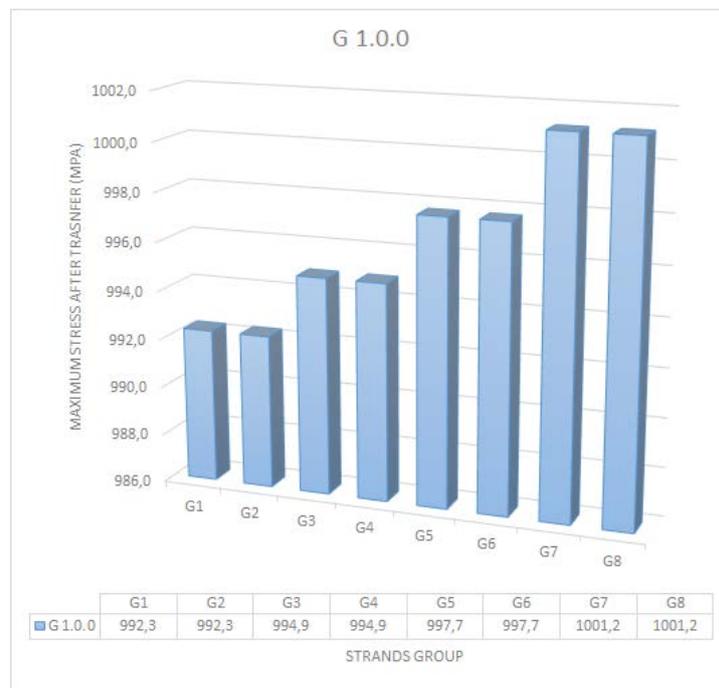


Figure 22. Maximum tension stress in the strands after transfer in reference beam G 1.0.0

Figure 23 described the tensions development in the strands group related to the beams G 1.1.1, G 1.1.2, G 1.1.3. The values of maximum stress after transfer in strands group G1 are the same to that achieved to equivalent strands from the reference beam G 1.0.0. The stress obtained in the other strands group are significantly higher than that from the control beam. For instance, for strands group G8 the values of maximum stress obtained after transfer is 1009.1 MPa to 1009.8 MPa (depending of debonding length) compared to the obtain value of 1001.2 MPa on to control beam (G 1.0.0).

Similar results were obtained in the case of the beams G 1.2.1, G 1.2.2, G 1.2.3, with the only difference that the strands group with the highest stress losses are G2. Debonded length does not influence the stress losses in debonded strands for the two illustrated cases. Further investigations must be made to establish regarding the influence of debonded strands lengths situated at the extremity of the beams.

From comparing these two simulations it results that the positions of the partially debonded strands in the corner of the total strands displacement do not have a quantifiable impact.



Figure 23. Maximum tension stress in the strands after transfer for beams G 1.1.1, G 1.1.2, G 1.1.3

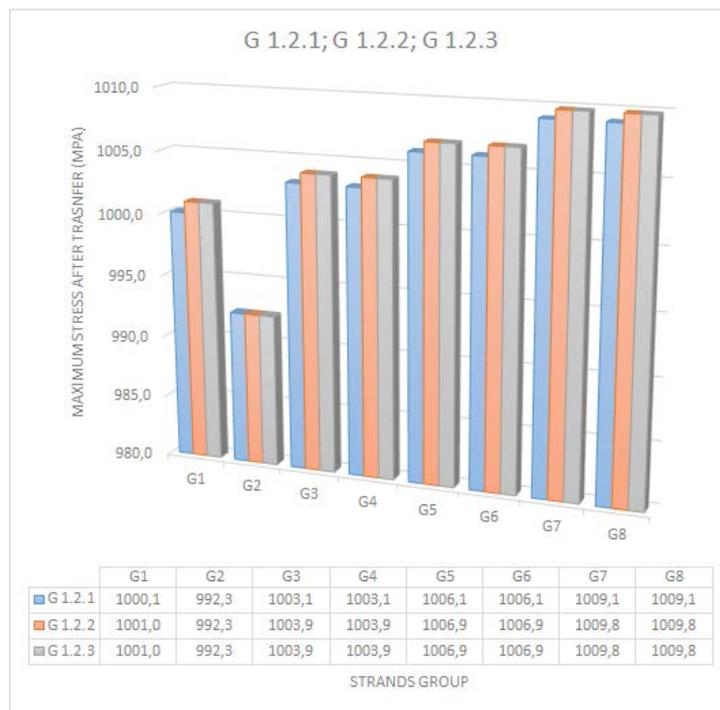


Figure 24. Maximum tension stress in the strands after transfer for beams G 1.2.1, G 1.2.2, G 1.2.3

In figure 25 and figure 26 we can notice similar principles as were detailed previous with the particularities resulted from the debonded strands group G3 respectively G4.

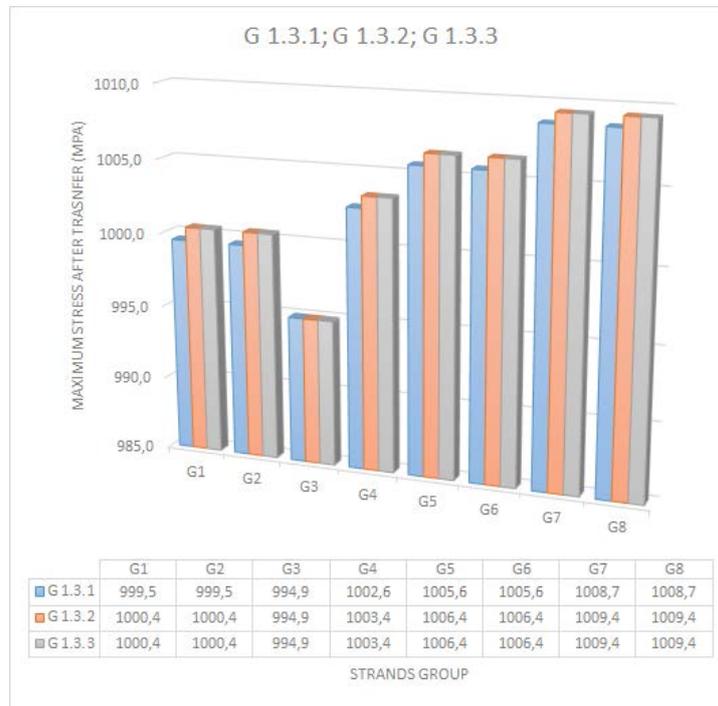


Figure 25. Maximum tension stress in the strands after transfer for beams G 1.3.1, G 1.3.2, G 1.3.3

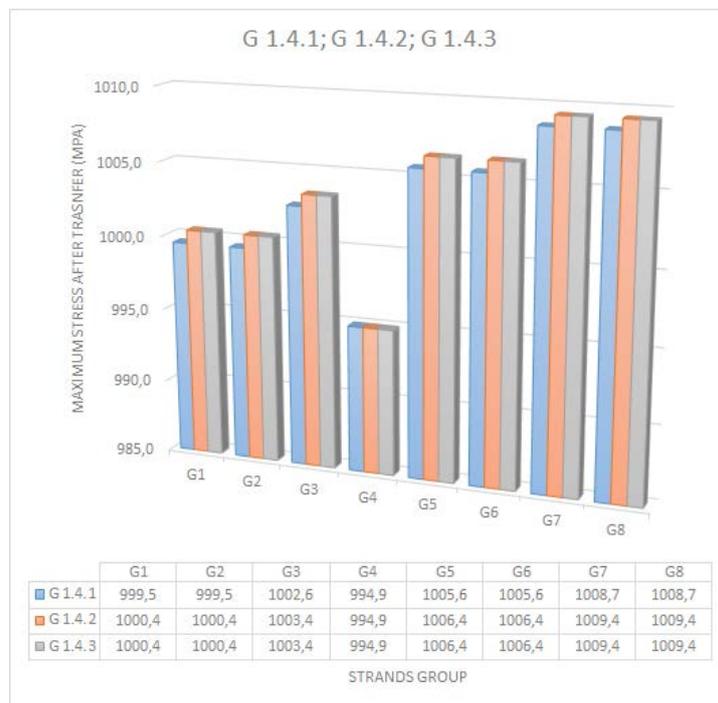


Figure 26. Maximum tension stress in the strands after transfer for beams G 1.4.1, G 1.4.2, G 1.4.3

Figure 27 and figure 28 illustrates the particularities for beams G 1.5.1, G 1.5.2, G 1.5.3 respectively for beams G 1.6.1, G 1.6.2 and G 1.6.3.

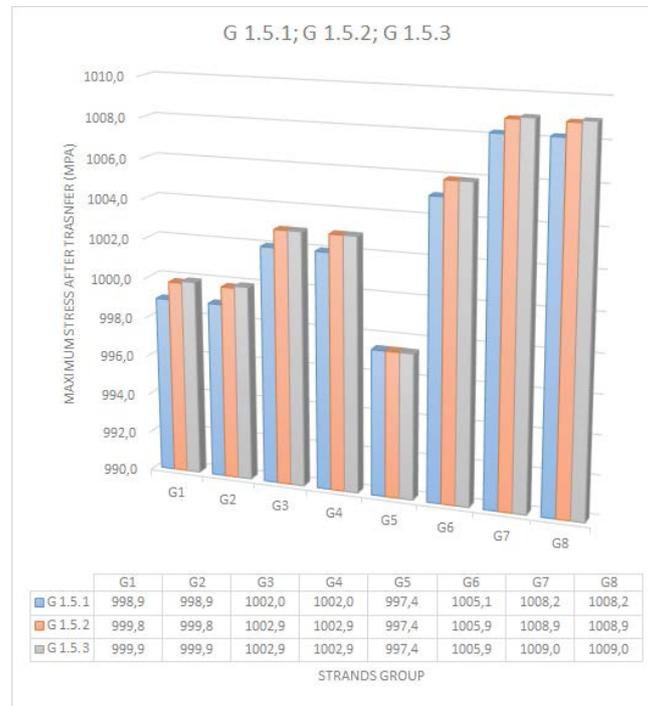


Figure 27. Maximum tension stress in the strands after transfer for beams G 1.5.1, G 1.5.2, G 1.5.3

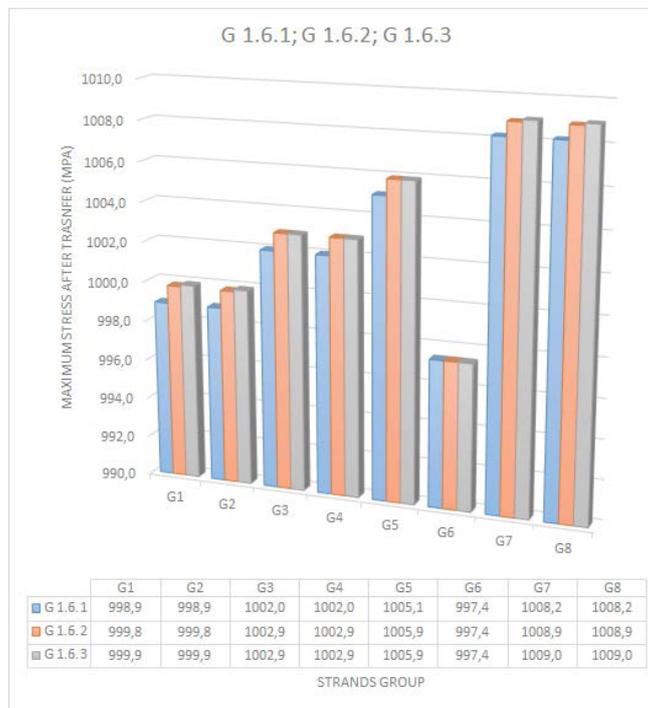


Figure 28. Maximum tension stress in the strands after transfer for beams G 1.6.1, G 1.6.2, G 1.6.3

Figure 29 and figure 23 relate the maximum stress after transfer when the partially debonded strands are situated the closest to the y-y axis.

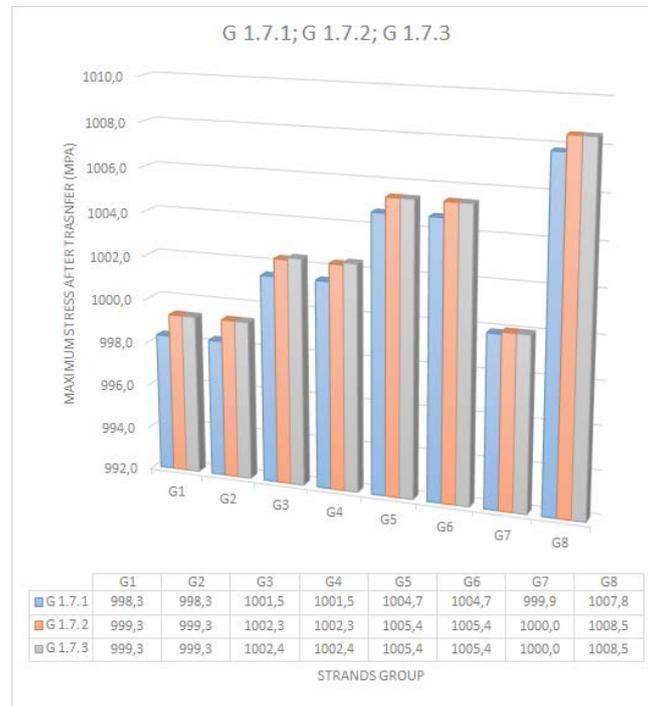


Figure 29. Maximum tension stress in the strands after transfer for beams G 1.7.1, G 1.7.2, G 1.7.3

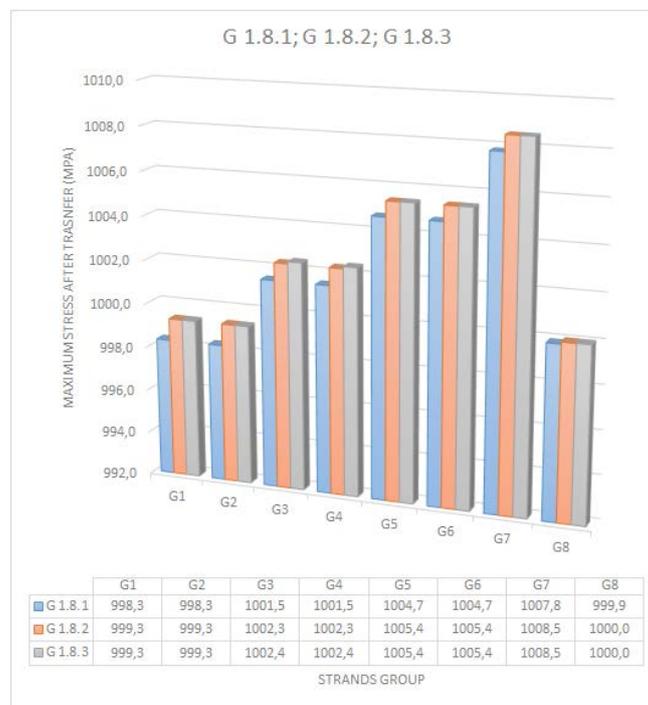


Figure 30. Maximum tension stress in the strands after transfer for beams G 1.8.1, G 1.8.2, G 1.8.3

Figure 31 illustrates the M_y (bending moment) development in the support area of the beams in the top fibers. The values mentioned in figure 31 are taken from the envelope. In the first column are mentioned the beams considered, in column 2 the values obtained in the case of a strands debonded length of 2.50 m, in column 3 the values obtained in the case of a strands debonded length of 2.75 m and in column 4 the values obtained in the case of a strands debonded length of 3.00 m. The biggest bending moment is obtained in the case of the reference beam (G 1.0.0) and the smallest in the case of beams G 1.1.1, G 1.1.2, G 1.1.3, G 1.2.1, G 1.2.2 and G 1.2.3. We can state that as the farther are the partially debonded strands from the y-y axis the smaller the bending moment in the support area of the beams is.

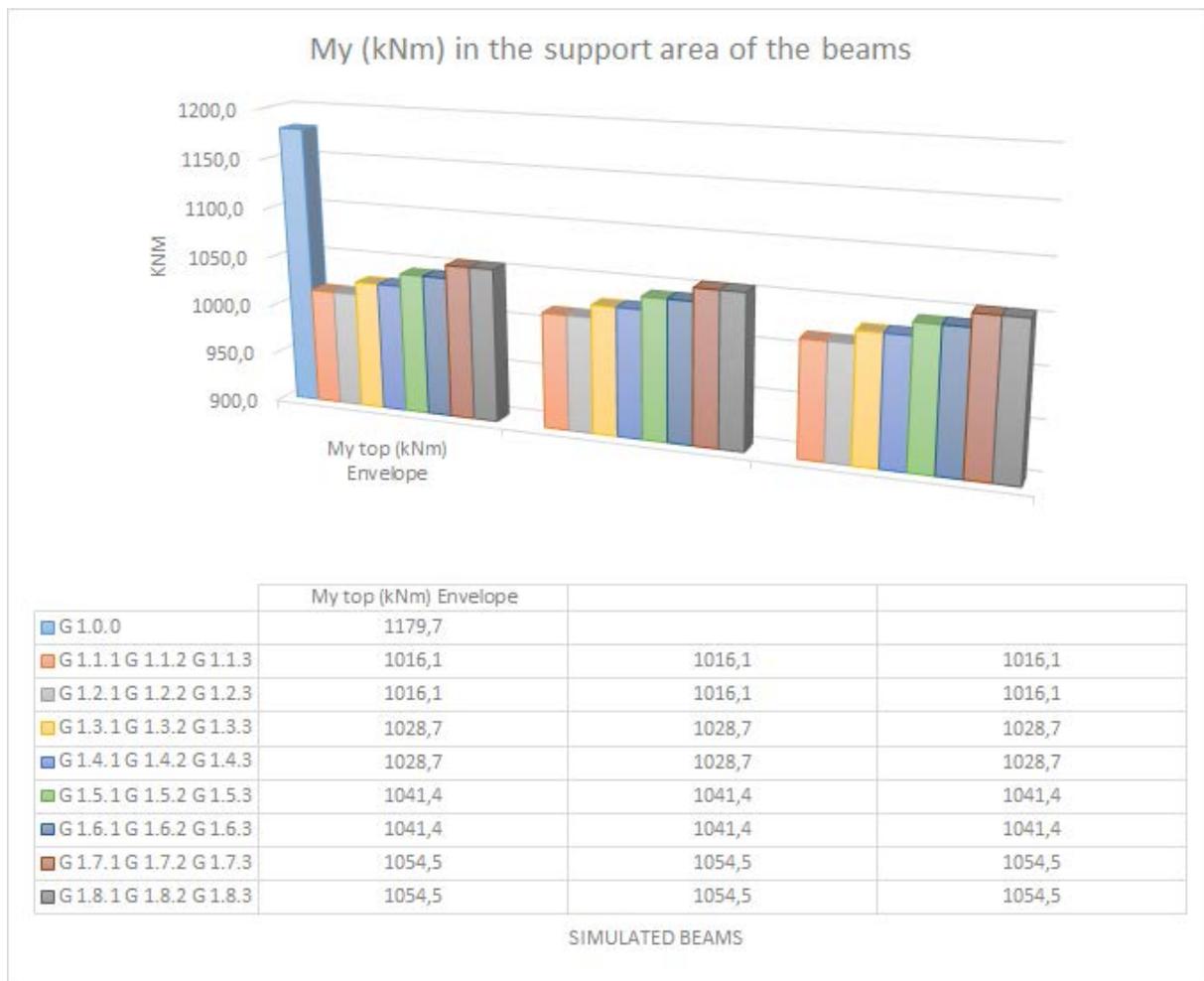


Figure 31. M_y (kNm) in the support area of beams in top fibers (envelope)

4. Conclusions

After interpreting the previous results, we can state the following generally applicable rules.

In the case of the beams with fully bonded strands the stress losses after transfer are decreasing from the strands situated near of the extreme fiber to those situated closer to the y-y axis of the beam. The strands situated at the same row have the same stress losses.

Regarding using partially debonded strands the stress losses are decreasing comparing to the beams with fully bonded strands excepting the debonded strands. By using partial debonded strands in

designing of prestress precast concrete beams the strands are used more efficiently, the value of stress after transfer getting closer to the initial stress value.

From our research result that the shorter the length of partially debonded strand is, the higher the stress losses are. A higher number of simulations must be done to obtain a certain verdict.

Regarding M_y (bending moment) in the support area of the beams the highest values is obtained in the cases of the beams with fully bonded strands. For the beams with partially debonded strands the smallest values is obtained in the situation in which the debonded strands are situated further from the y-y axis. The value of the bending moment increases as the partially debonded strands are closer to the y-y axis. Regarding influence of the partially debonded strands length on to bending moment it is inconclusive. It is necessary to run a higher number of simulations considering more debonded lengths. The blanketing proposal must fulfil the requirements of limiting of tensile stresses in the concrete at the top fibres at transfer and the ability to sustain the imposed load tensions at the bottom fibres with the resulting reduced prestress at the debonded sections. Also, the blanketing proposal must satisfy the technical and economic criteria.

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