Recommendations on end zone reinforcement detailing of pre-tensioned concrete girders

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Abstract

This paper presents an assessment of the efficiency of different end zone reinforcement detailing for pre-tensioned concrete girders. The evaluation is performed through a numerical parametric study of 10 different reinforcement lay-outs. The implemented lay-outs are compared in terms of crack control and design recommendations for efficient end zone reinforcement detailing are formulated.

Keywords: Pre-tensioning; end zone reinforcement; prestressed concrete; crack control.

1 Introduction

Even though the use of pre-tensioned prestress concrete elements is widespread nowadays, field observations still show that non-negligible end zone cracking can occur as depicted in figure 1.

Figure 1: End zone cracks in pre-tensioned girder [1]

These cracks can damage the structural integrity of the element and should therefore be avoided or at least controlled. This paper presents a numerical parametric study of the crack control efficiency of different end zone reinforcement lay outs. This is achieved by comparing the end zone strain field of 10 implemented reinforcement lay outs.

2 Numerical model

The numerical model consists of 2 stages [1]. In the first stage, the transfer of the prestress force and the associated transfer length is evaluated on a local scale, taking into account the concrete confinement of the strand including possible splitting failure. In the second stage, a full scale analyses of the end zone is performed taking into account the nonlinear material behaviour. For a full description of the numerical model, reference is made to [2].

3 Parametric study

10 models, 1 reference and 9 variations of different anchorage zone reinforcement lay outs, are evaluated numerically. Figure 2 and table 1 schematically show the implemented end zone reinforcement lay outs. Rebar diameters $Ø_1$, $Ø_2$, $Ø_3$, rebar spacing S1, S2 and the amount of stirrups used (n), are varied. Due to symmetry, only halve of the reinforcement detailing is shown.

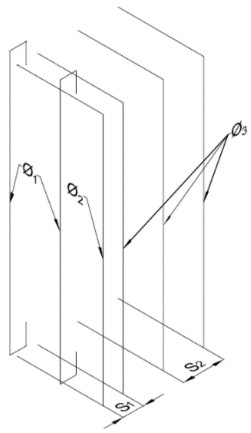

Figure 2:. Reinforcement detailing (variation 5)

Table 1. Implemented reinforcement variations

Variation	$Ø_1$ [mm]	$Ø_2$ [mm]	$Ø_3$ [mm]	S_1 [mm]	S_2 [mm]	n
Ref.	8	10	12	50	50	6
1	9,2	8,3	12	50	50	6
2	11.3	2.2	12	50	50	6
3	1.8	13.8	12	50	50	6
4	8	10	8.9	50	25	10
5	8	10	15.5	50	100	4
6	8	10	12	82	82	6
7	8	10	12	115	115	6
8	8	10	12	50	50	9
9	8	10	12	50	50	12

Figures 3 and 4 show the vertical strain field in the spalling and bursting region of the end zone. Only the variations which specifically target the spalling strain, by varying $Ø_1$ and $Ø_2$, are shown in figure 3. The reinforcement detailing focussing on the bursting strain, which vary $Ø_3$, and the rebar spacing, are shown in figure 4. Strain values larger the critical cracking strain, 98 µstrain, indicate that the concrete is cracked. Better crack control is therefore also achieved for reinforcement lay outs which depict lower strain values in the cracked sections.

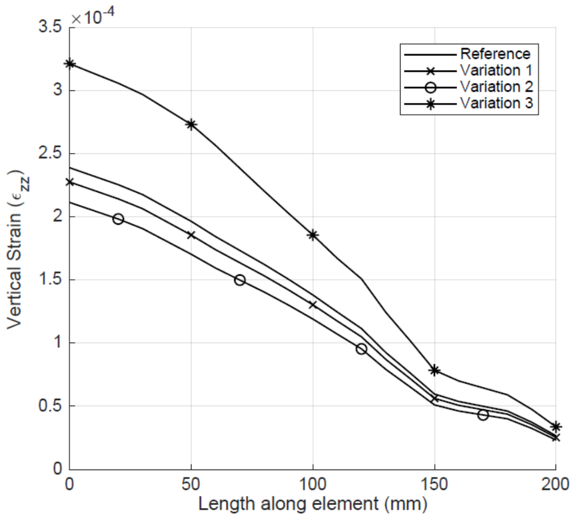

Figure 3: Spalling strain values

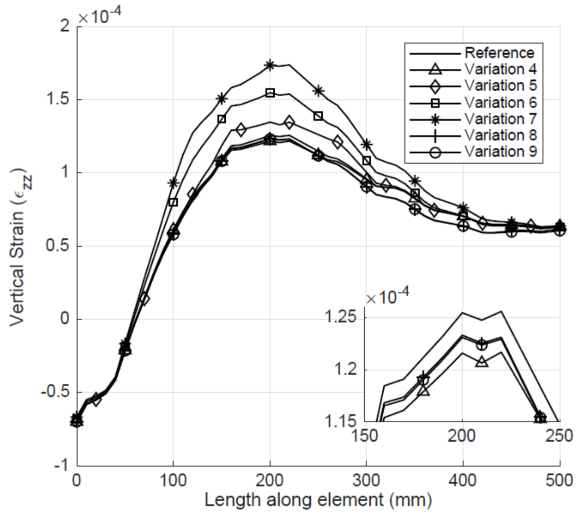

Figure 4: Bursting strain values

4 Discussion and conclusion

From the resulting end zone strain fields, the following conclusions can be drawn:

- The best spalling strain control is achieved by placing rebars with larger diameters as close to the end face of the element as possible. This is illustrated in figure 3 by the decent spalling strain control of variation 2. Figure 3 furthermore shows that the spalling strains decrease rapidly further inwards of the element. It can be concluded that the spalling crack control of the stirrups located further inwards of the element is therefore limited.
- The best bursting strain control is achieved by dividing the reinforcement along the critical area (20% to 60% of the transfer length, equal to 625mm). Rebar spacing of approximately 50mm provides a good distribution of the end zone bursting stress. Variation 5, 6, and 7 have larger rebar spacing and consequently, larger strain values. The bursting strains of variations 4 and 8 show minor differences.

References

[1] Okumus P., Oliva M., Strand debonding for pretensioned bridge girders to control end cracks, Structural Journal, 2014, 201-210

[2] Steensels R., Vandewalle L., Vandoren B., and Degée H. A two-stage modelling approach for the analyses of the stress distribution in anchorage zones of pre-tensioned, concrete elements, Engineering Structures, 2017, **143**: 384-39