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DESIGNING OF PRESTRESSED PRECAST CONCRETE BEAMS IN CHLORIDES ENVIRONMENT

BY

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Abstract. The proper design of prestressed precast concrete beams represents a difficult task, the parameters involved in design being correlated even with the surrounding environment of the members. In the case of the members situated in the chloride environment, the task of designing a suitable member is harder due to the fact that are not allowed cracks. According to Eurocode 2, active and passive reinforcement exposed to chloride environments will corrode, the integrity of the members being at risk. As it known the development of cracks may occur in all the construction stages: transfer of prestressing, storage yard, transport, final support, superimposed dead load or at the end of the designed working life. A rigorous control is necessary for creating a satisfactory element. In this paper, it will be showed how by placing the same prestressed precast concrete beam in different environments, the overall compliance of the element will be altered due to the different restriction according to the designed norms. To highlight these particularities the IDEA StatiCA software was used.

Keywords: corrosion; models; chloride; cracks; IDEA Statica.

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1. Introduction

Deterioration of prestressed concrete members due to chloride environment represent a topic of interest (Fumin *et al.*, 2011), the proper evaluation of the design working life for existing and for planned structures being very important (Darmawan & Stewart, 2007). The service life of a member/structure under chloride attack consists of two definite stages: the initiation period and the propagation period. Initiation period is considered to be the time from exposure until chloride has penetrated the concrete over and the chloride content of the concrete in contact with the active and passive reinforcement is high enough to start corrosion. The propagation period is the time from when the reinforcement starts to corrode until a critical limit has been reached. In the case of prestressed concrete members, the initiation period may be non-existent if the member exhibits cracks from the early construction and services stages (Pascu & Zybaczinski, 2012). In this case, the propagation period starts from the incipient phase.

The corrosion process leads to several faults: longitudinal cracking of concrete cover due to expansive of reinforcement, reinforcement cross-section reduction and the degradation of the bond between steel and concrete. Consider these effects, the service life of a prestressed concrete member can be considerably reduced or fail from the design phase. According to the current norms, the design working life of prestressed precast members is of 100 years (Cadar *et al*., 2004). To fulfil the currents demands according to Eurocode 2 the prestressed precast concrete members situated in chloride environment must not present cracks in any construction and service stage (Tuns & Florea, 2010).

2. Experimental Phase

To illustrate the difference occurring when design prestressed precast members situated in chloride environment, a study was carried out a number of 4 beams. The IDEA StatiCA software was used to accomplish the simulations.

The following characteristics of the beams were considered:

- beam length: 25.5 m; static scheme, sections as is shown in Fig. 1;

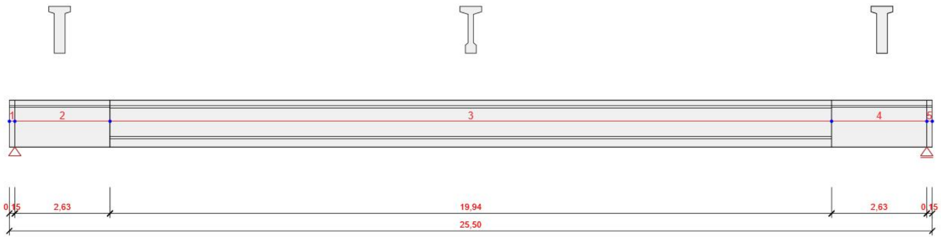


Fig. 1 – Static scheme.

• concrete grade: C50/60:

• the concrete curing was considered naturally (not the case of heat curing);

• strands: Y1860S7-15.2;

• strands displacement as is shown in Figs. 2 and 3;

• debonded length of strand group G3: 3.00 m;

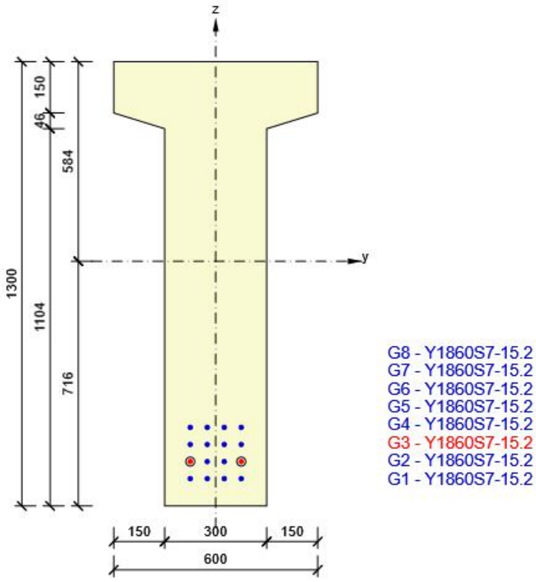


Fig. 2 – Strand displacement in Section 1.

• initial stress: 1,100.0 MPa;

• passive reinforcement: B500C;

• load cases (self-weight, permanent load: 9.1 kN/m, variable load: 15.4 kN/m, load per stage of execution G 5: 1.0 kN/m);

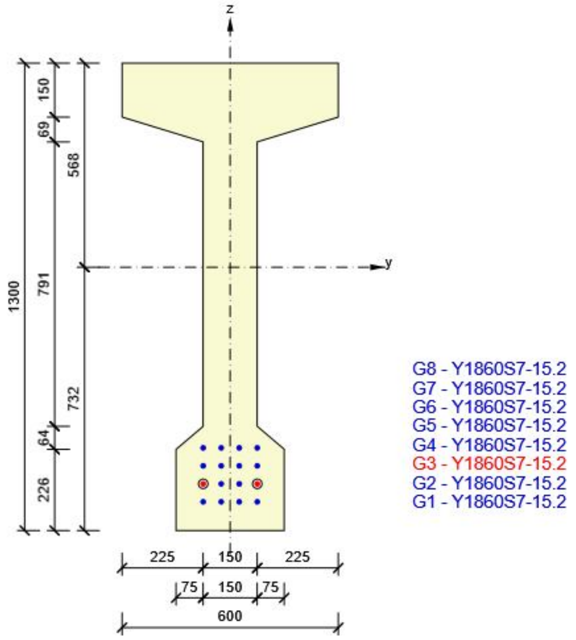


Fig. 3 – Strand displacement in Section 2.

• construction and service stages: ST(1) – casting, ST(2) – transfer of prestressing, ST(5) – final support, ST(6) – superimposed dead load, ST(7) – end of design working life, as is shown in Fig. 4.

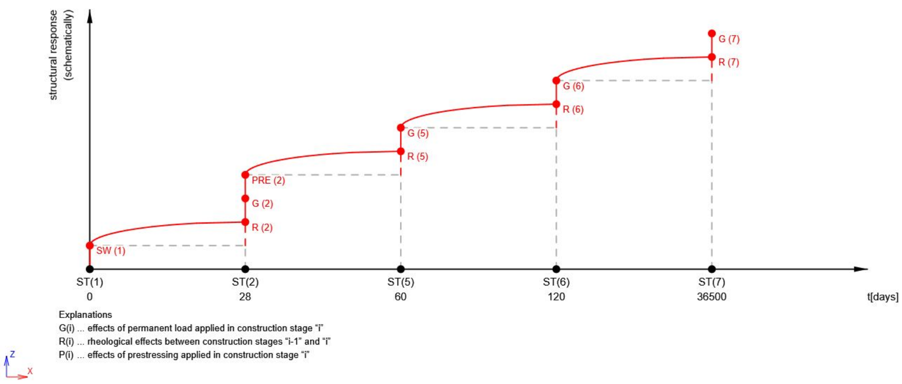


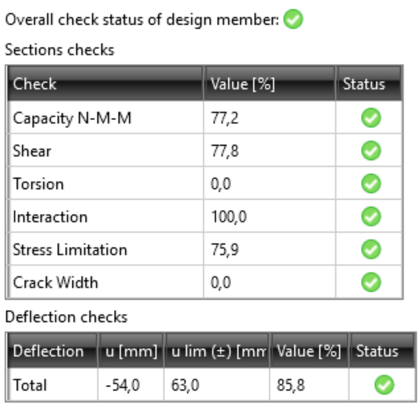
Fig. 4 – Construction stages for beam consider.

In Table 1 are illustrated the environment's condition for each beam considered in the analysis (Kiss & Onet, 2008). To simplify the simulations, only the effects of carbonation and chlorides were considered.

Table 1
Simulated Beam Environments

Beam	Carbonation	Chlorides
Beam 1	XC1 – dry or permanent wet	no risk of chlorides
Beam 2	XC1 – dry or permanent wet	XD1 – moderate humidity
Beam 3	XC2 – wet, rarely dry	XD2 – wet, rarely dry
Beam 4	XC4 – cyclic wet and dry	XD3 – cyclic wet and dry

The simulations were carried out, the results being presented in Fig. 5 for Beam 1, Fig. 6 for Beam 2, Fig. 7 for Beam 3 and Fig. 8 for Beam 4. It could be noticed that beams have the same stress development. The values for capacity N-M-M, shear, stress limitation and for deflection are the same for all 4 beams.

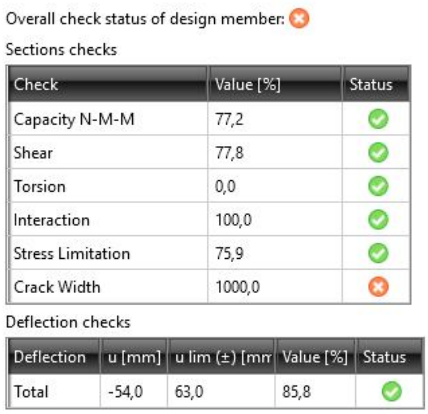

Overall check status of design member: ✓
Sections checks

Check	Value [%]	Status
Capacity N-M-M	77,2	✓
Shear	77,8	✓
Torsion	0,0	✓
Interaction	100,0	✓
Stress Limitation	75,9	✓
Crack Width	0,0	✓

Deflection checks

Deflection	u [mm]	u lim (±) [mn	Value [%]	Status
Total	-54,0	63,0	85,8	✓

Fig. 5 – Results obtained for Beam 1.

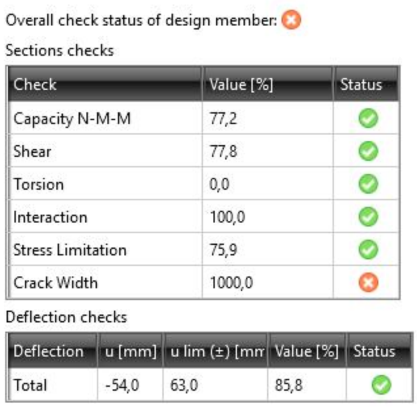

Overall check status of design member: ✗
Sections checks

Check	Value [%]	Status
Capacity N-M-M	77,2	✓
Shear	77,8	✓
Torsion	0,0	✓
Interaction	100,0	✓
Stress Limitation	75,9	✓
Crack Width	1000,0	✗

Deflection checks

Deflection	u [mm]	u lim (±) [mn	Value [%]	Status
Total	-54,0	63,0	85,8	✓

Fig. 6 – Results obtained for Beam 2.


Overall check status of design member: ✗
Sections checks

Check	Value [%]	Status
Capacity N-M-M	77,2	✓
Shear	77,8	✓
Torsion	0,0	✓
Interaction	100,0	✓
Stress Limitation	75,9	✓
Crack Width	1000,0	✗

Deflection checks

Deflection	u [mm]	u lim (±) [mn	Value [%]	Status
Total	-54,0	63,0	85,8	✓

Fig. 7 – Results obtained for Beam 3.


Overall check status of design member: ✗
Sections checks

Check	Value [%]	Status
Capacity N-M-M	77,2	✓
Shear	77,8	✓
Torsion	0,0	✓
Interaction	100,0	✓
Stress Limitation	75,9	✓
Crack Width	1000,0	✗

Deflection checks

Deflection	u [mm]	u lim (±) [mn	Value [%]	Status
Total	-54,0	63,0	85,8	✓

Fig. 8 – Results obtained for Beam 4.

Making reference to the crack's development was observed that only in the case of Beam 1 (with no risk of chlorides) the checks were satisfied. Cracks do not appear for frequent combination – effective tensile stress of concrete according to clause 7.1 (2) from SR EN 1992-1-1 (2004) is not exceeded in most tensioned concrete fibres.

For Beams 2, 3 and 4 the checks regarding cracks development are not satisfied. The distance of prestressing reinforcement and the tensile zone is present as a negative value because one or more tendons lie in the tensile zone of the cross-section. Therefore, the check of the decompression limit according to clause 7.3.1, Table 7.1 N from SR EN 1992 is not satisfactory. Calculated crack width is higher than crack width limit, this being unacceptable because it favours the corrosion of the reinforcements (Moser *et al*., 2012).

3. Conclusions

Usually, the cracks should be limited so as not impair the proper functioning or durability of the element/structure or to lead to an unacceptable aspect. In the case of elements situated in chlorides environments, cracks are not allowed because they favour corrosion of reinforcement. This aspect was illustrated previously in the simulations carried out. It can be noticed that the parameters regarding exposure class influence in a significant manner the overall design of the beams. Thus, is necessary proper identification of the environmental condition in order to manage a correct design.

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REFERENCES

Cadar I., Clipii T., Agneta T., *Beton armat*, Ediția a 2-a, 2004.

Darmawan S., Stewart M., *Spatial Time-Dependent Reliability Analysis of Corroding Pretensioned Prestressed Concrete Bridge Girders*, Structural Safety, **29**, *1*, 16-31 (2007).

Fumin L.,YingshuY., Chun-Qing L., *Corrosion Propagation of Prestressing Steel Strands in Concrete Subject to Chloride Attack*, Construction and Building Materials, **25**, *10*, October 2011, 3878-3885.

Kiss Z., Oneț T., *Proiectarea structurilor din beton armat după SR EN 1992-1*, 2008.

Moser R., Singh P., Kahn L., Kurtis K., *Chloride-Induced Corrosion Resistance of High-Strength Stainless Steels in Simulated Alkaline and Carbonated Concrete Pore Solutions*, Corrosion Science, **57**, April 2012, 241-253.

Pascu R., Zybaczinski A., *Beton precomprimat. Calcul după Eurocode 2*, 2012.
Tuns I., Florea N., *Beton precomprimat Vol.1*, 2010.
* * * *SR EN 1992-1-1/2004 Proiectarea structurilor din beton armat.*

PROIECTAREA GRINZILOR PREFABRICATE DIN BETON PRECOMPRIMAT ÎN MEDII CU CLORURI

(Rezumat)

Proiectarea eficientă a grinzilor prefabricate din beton precomprimat reprezintă o sarcină dificilă întrucât proiectarea corespunzătoare a acestora este corelată inclusiv cu parametri a căror valoare depinde de mediul înconjurător în care vor fi amplasate. În cazul elementelor situate în medii cu cloruri, proiectarea corespunzătoare a elementelor este mai restrictivă întrucât nu sunt premise fisuri. Conform Eurocodului 2, armăturile active şi pasive expuse la medii cu cloruri vor coroda, integritatea elementului fiind în pericol. După cum este cunoscut, dezvoltarea fisurilor poate lua loc în toate stadiile de construcţie: la transferul tensiunilor, în etapa de depozitare, transport, exploatare sau la sfârşitul duratei de viaţă a elementului. Este necesar un control riguros pentru a crea un element corespunzător. În această lucrare este ilustrat cum prin amplasarea aceluiaşi element în diferite medii înconjurătoare, poate fi influenţat gradul de conformitate a acestuia conform normelor în vigoare. Pentru a evidenţia aceste particularităţi a fost utilizat programul IDEA StatiCA.