8.4 Hollow section column

8.4.1 Description

The component based finite element method (CBFEM) for the hollow section column base verified to component method (CM) is described below. Compressed column is designed as class 3 cross section. The sensitivity study is prepared for the size of the column, dimension of base plate, grade of concrete, and dimension of concrete block. Four components are activated: the column flange and web in compression, the concrete in compression including grout, the anchor bolt in tension and welds. This study is mainly focused on two components: concrete in compression including grout and anchor bolt in tension.

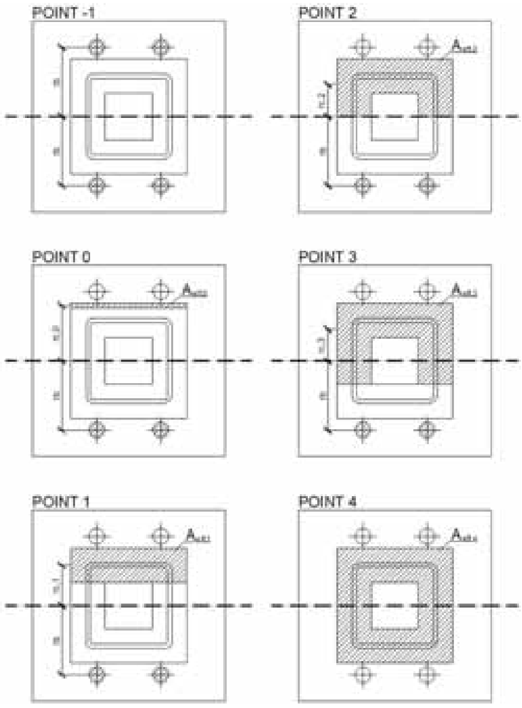

Fig. 8.4.1 Significant points of multilinear interaction diagram of square hollow section

8.4.2 Verification of resistance

In following example, the column from square hollow section SHS 150x16 is connected to concrete block with the area dimensions $a' = 750$ mm, $b' = 750$ mm and height $h = 800$ mm from concrete grade C20/25 by the base plate $a = 350$ mm; $b = 350$ mm; $t = 20$ mm from steel S420. Anchor bolts are designed 4 x M20, A_s = 245 mm^2 with head diameter a = 60 mm from steel 8.8 with offset at top 50 mm and left -20 mm. Grout has the thickness of 30 mm.

Results of analytical solution are presented as interaction diagram with distinctive points. Detailed description of points -1, 0, 1, 2 and 3 is shown in Fig. 8.4.1, see (Wald, 1995) and (Wald et al., 2008), where point -1 represents pure tensile force, point 0 pure bending moment, points 1 to 3 combined compressive force and bending moment, and point 4 pure compressive force.

In CBFEM, the prying forces occur in case of loading in pure tension loading; while in CM, no prying forces are developed by limiting the resistance to 1-2 failure mode only, see (Wald et al, 2008). Due to allowing the prying forces, the difference in resistance is about 10 %. The numerical model of column base is shown in Fig. 8.4.2. Results by CBFEM are presented by the stress distribution for point 0 and 3, displayed in Fig. 8.4.3 and Fig. 8.4.4 and compared on interaction diagram in Fig. 8.4.5.

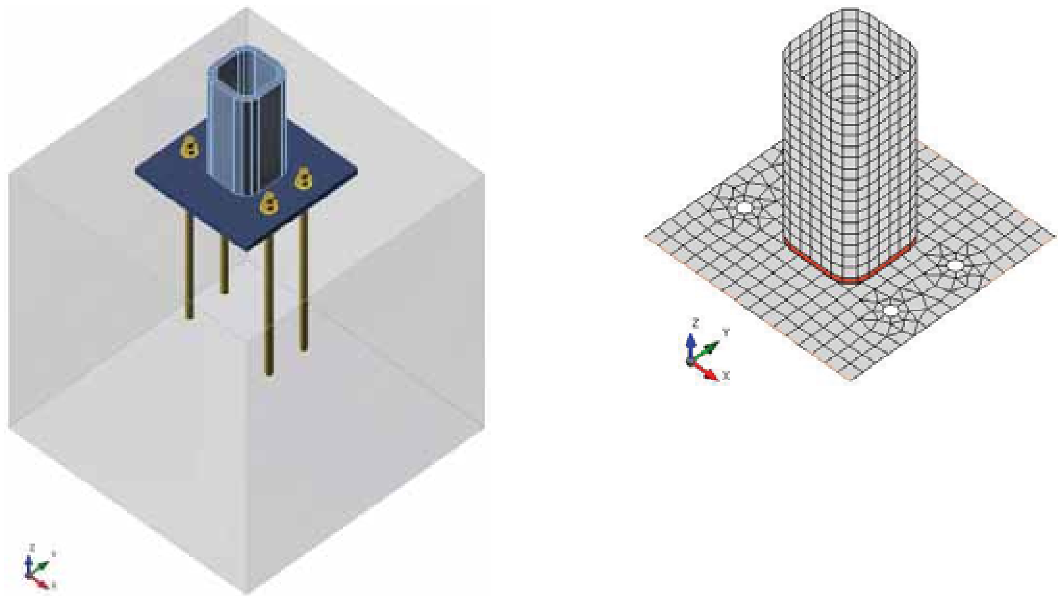

Fig.8.4.2 The column base for column SHS 150x16 and selected meshed of base plate

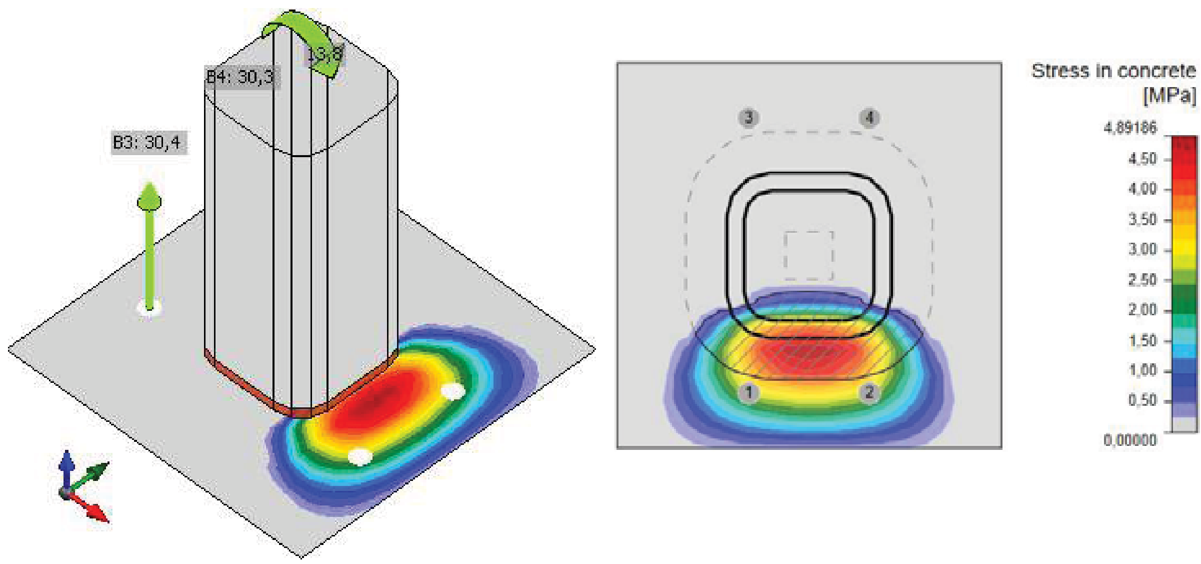

Fig. 8.4.3 CBFEM results for point 0, e.g. pure bending moment

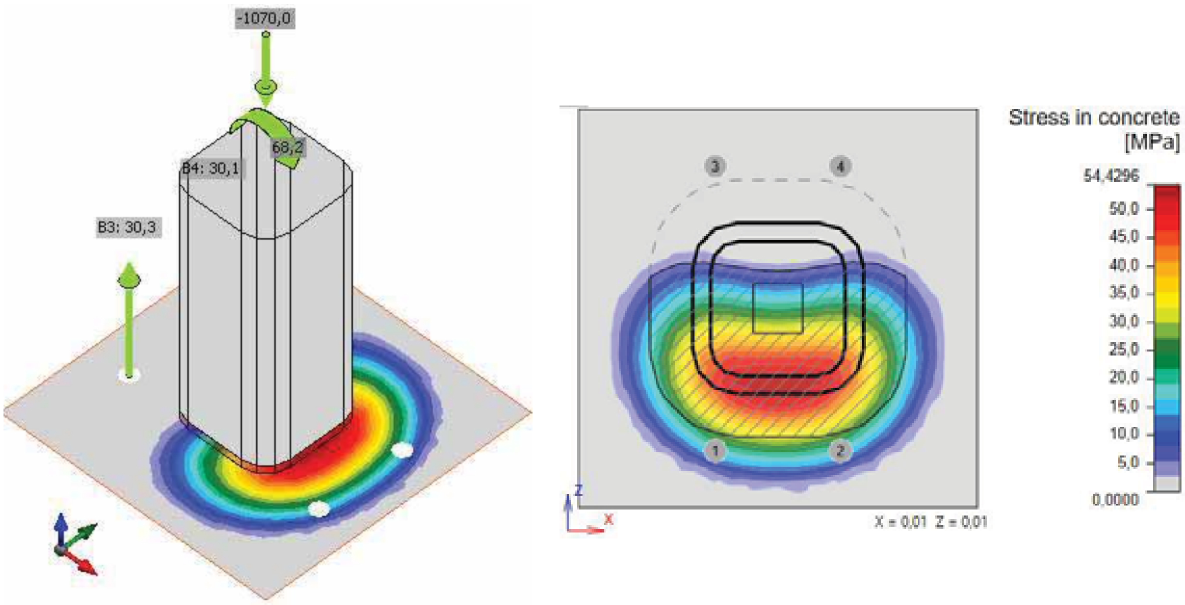

Fig. 8.4.4 CBFEM results for point 3, e.g. compressive force and bending moment

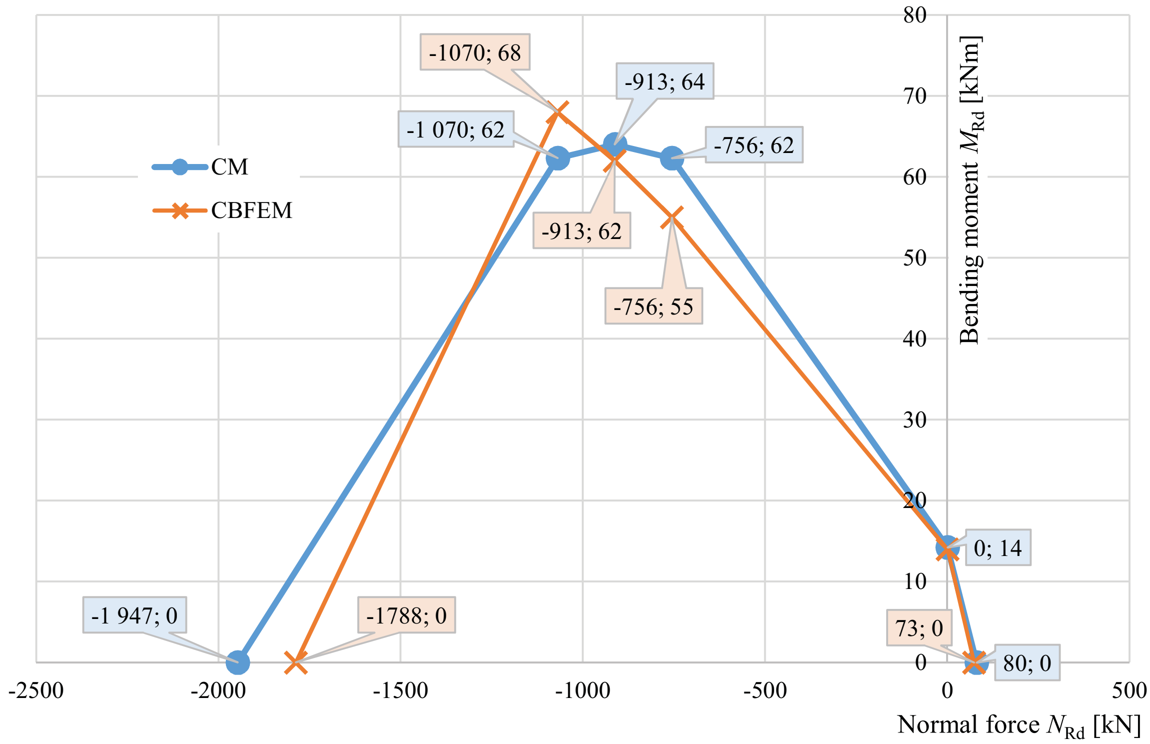

Fig. 8.4.5 Comparison of results of prediction of resistance by CBFEM and CM on interaction diagram for column base of column cross section SHS 150x16

8.4.3 Sensitivity study

The sensitivity study is prepared for the column cross section size, dimensions of the base plate, concrete grade, and dimensions of the concrete block. The columns are selected SHS 150x16, SHS 160x12.5 and SHS 200x16. The base plate is designed with area dimensions 100 mm, 150 mm and 200 mm larger than the column cross section. The base plate thickness is 10 mm, 20 mm and 30 mm. The foundation block is from concrete grade C20/25, C25/30, C30/37 and C35/45 with height for all cases 800 mm and with area dimensions 100 mm, 200 mm, 300 mm and 500 mm larger than the dimensions of the base plate. One parameter was changed while the others were held constant. The parameters are summarized in Tab. 8.4.1. The fillet welds with thickness a = 8 mm were selected. The joint coefficient for high quality grout is taken as β_j = 1,0. Steel plates are from S420 with anchor bolts M20 grade 8.8 in all cases.

Table 8.4.1 Selected parameters

Column cross section	SHS 150x16	SHS 16x12,5	SHS 200x16
Base plate offset, mm	100	150	200
Base plate thickness, mm	10	20	30
Concrete grade	C20/25	C30/37	C35/45
Concrete pad offset, mm	100	300	500

For sensitivity study of column cross section, the concrete grade C20/25, the base plate thickness 20 mm, the base plate offset 100 mm and the concrete block offset 200 mm were used for varying parameter of column section. The comparison of CBFEM (marked IC) to analytical model by CM (marked An) is shown on the interaction diagrams in Fig. 8.4.6.

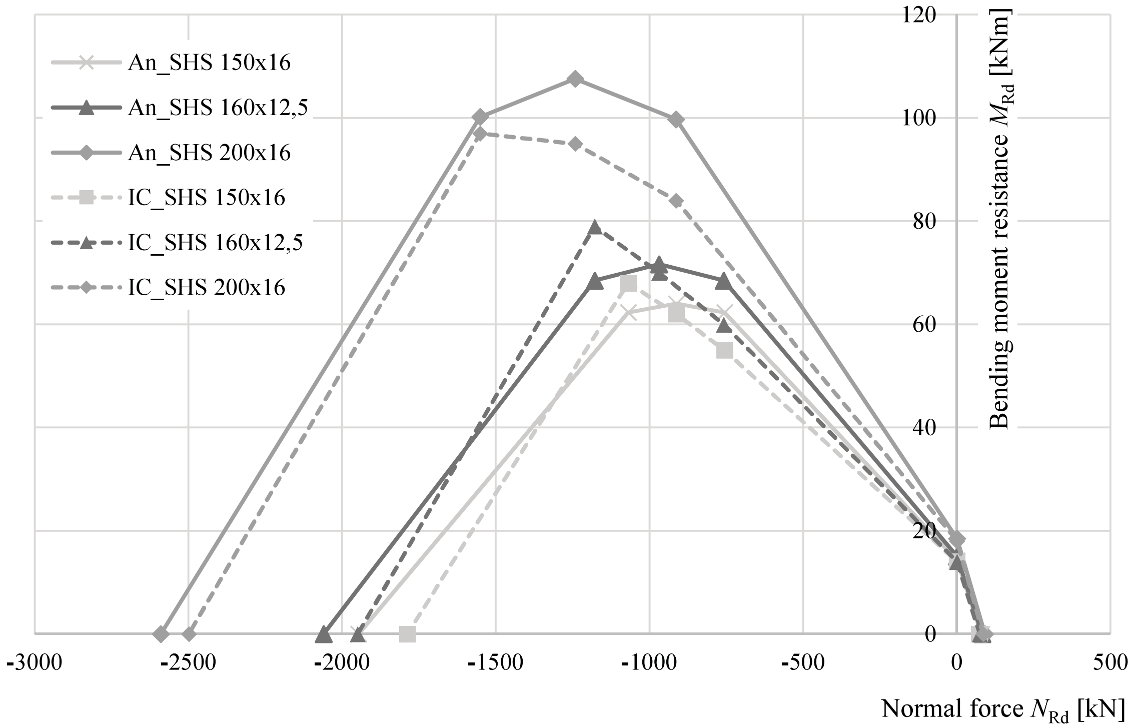

Fig. 8.4.6 Comparison of results of CBFEM (marked IC) to CM (marked An) for the different column cross sections

For sensitivity study of base plate offset, the column cross section SHS 200x16, concrete grade C25/30, base plate thickness 20 mm and concrete block offset 200 mm were selected. The comparison of interaction diagrams is in Fig. 8.4.7. The biggest difference is in the resistance in pure tension of large base plate where significant prying forces were present in CBFEM analyses, which are limited by analytical design.

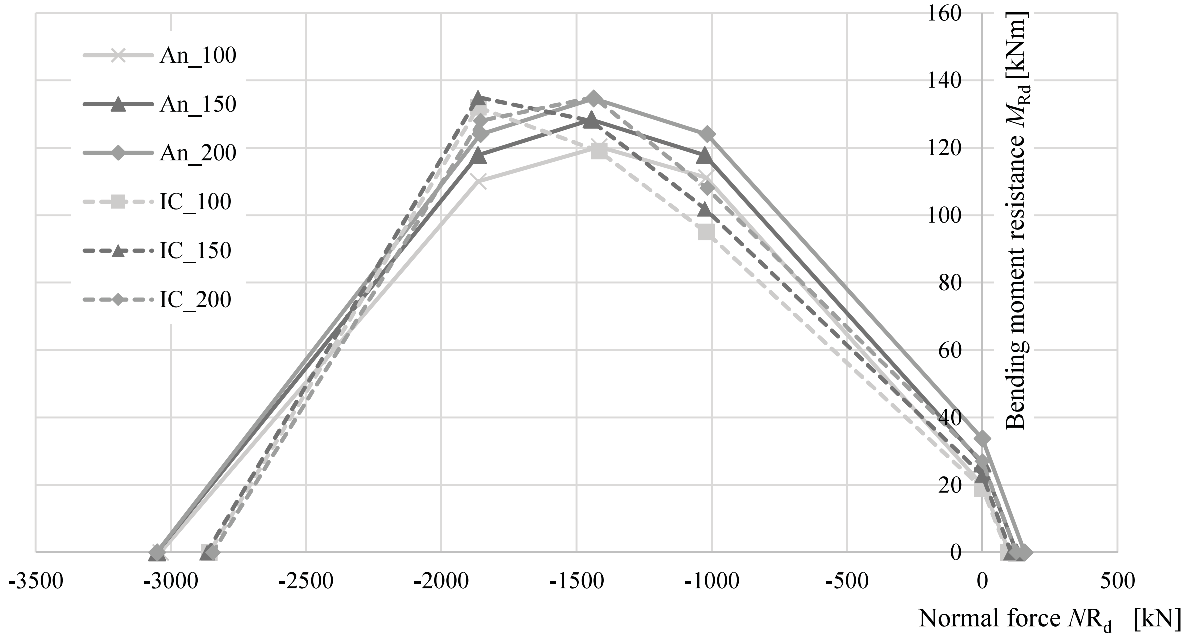

Fig. 8.4.7 Comparison of results of CBFEM (marked IC) to CM (marked An) for the different base plate offsets

For sensitivity study of base plate thickness, the column cross section SHS 200x16, concrete grade C25/30, base plate offset 100 mm and concrete block offset 200 mm were selected. 10 mm, 20 mm and 30 mm base plate thicknesses were used in this study. The comparison of interaction diagrams is in Fig. 8.4.8. The biggest difference is in the resistance in pure tension of thin base plate where significant prying forces were present in CBFEM analyses, which are limited in analytical design by CM.

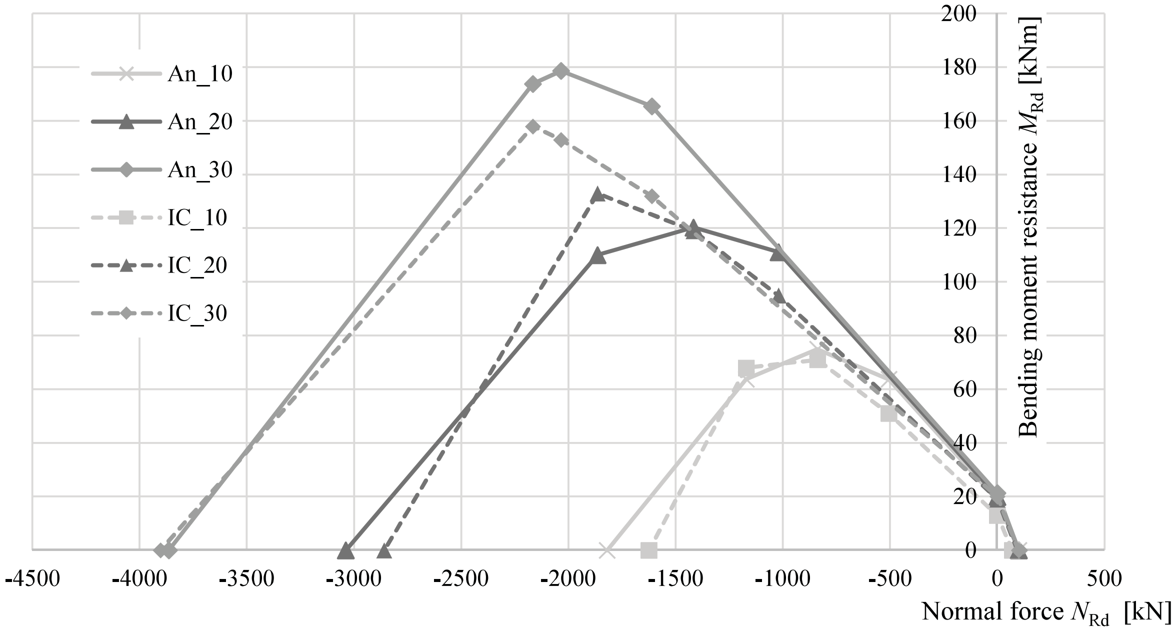

Fig. 8.4.8 Comparison of results of CBFEM (marked IC) to CM (marked An) for the different base plate thickness

For sensitivity study of concrete grade, the column cross section SHS 150x16, base plate thickness 20 mm, base plate offset 100 mm and concrete block offset 200 mm were selected. Concrete grades C20/25, C30/37 and C35/45 were used in this study. The comparison of interaction diagrams is in Fig. 8.4.9.

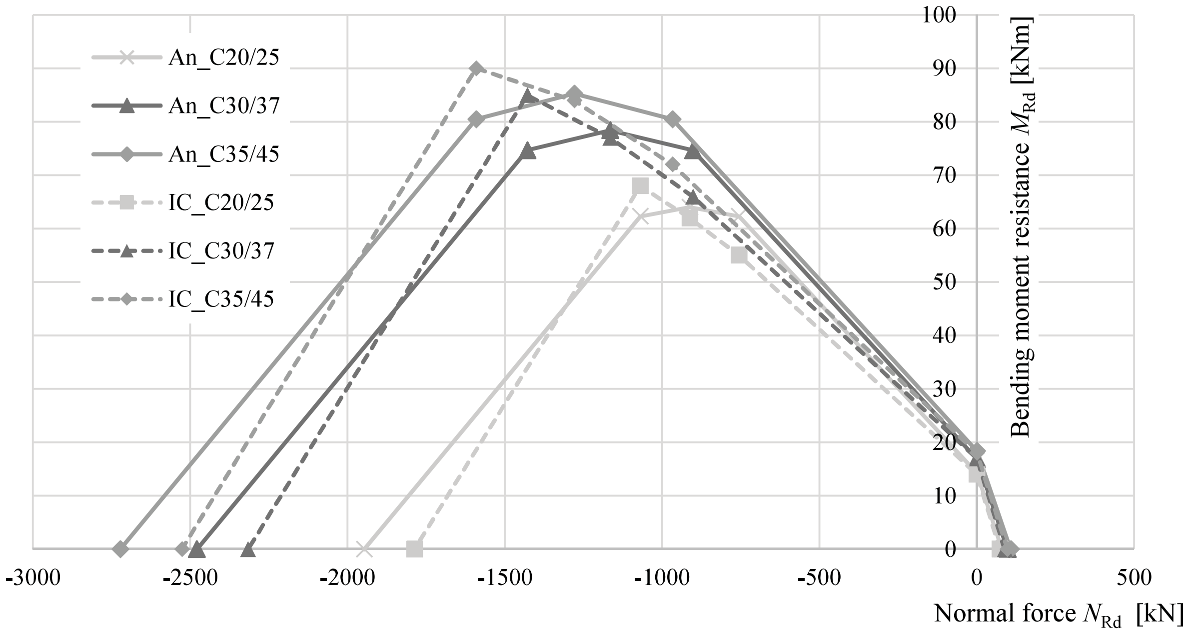

Fig. 8.4.9 Comparison of results of CBFEM (marked IC) to CM (marked An) for the different concrete grades

For sensitivity study of concrete block offset, the column cross section SHS 160x12.5, base plate thickness 20 mm, base plate offset 100 mm and concrete grade 25/30 were selected. 100 mm, 300 mm and 500 mm concrete block offsets were used in this study. The comparison of interaction diagrams is in Fig. 8.4.10.

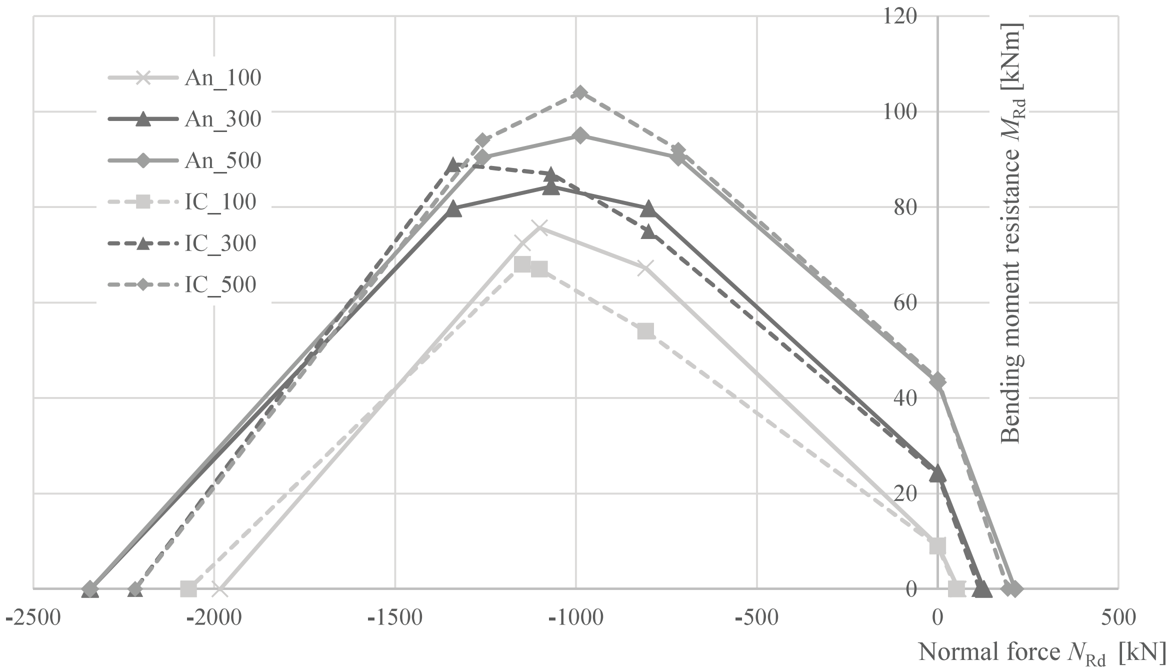

Fig. 8.4.10 Comparison of results of CBFEM (marked IC) to CM (marked An)
for the different concrete block offsets

The differences in prediction of resistance of column base by CBFEM and CN are mainly in accepting the prying forces in CBFEM and avoiding it by CM according to EN1993-1-8:2006.

Tab. 8.4.2 Interaction diagram comparison of CBFEM and CM

Difference CBFEM/CM	Point -1	Point 0	Point 1	Point 2	Point 3	Point 4
Maximum %	99,3	101,6	101,8	109,5	120,9	104,4
Minimum %	70,2	69,4	79,8	85,6	90,9	89,3

8.4.4 Benchmark case

Input

Column cross section

- SHS 150/16
- Steel S460

Base plate

- Thickness 20 mm
- Offsets at top 100 mm, on left 100 mm

- Welds 8 mm
- Steel S460

Anchors

- M20 8.8.
- Anchoring length 400 mm
- Offsets top layers 50 mm, left layers -20 mm
- Shear plane in thread

Foundation block

- Concrete C20/25
- Offset 200 mm
- Depth 800 mm
- Shear force transfer friction
- Grout thickness 30 mm

Loading

- Axial force N = -913 kN
- Bending moment M_y = 62,1 kNm

Output

- Plates $\varepsilon = 0{,}3$ %
- Anchor bolts 99,7 % ($N_{Ed} = 30{,}3$ kN $\leq N_{Rd,c} = 30{,}4$ kN (critical component concrete cone breakout)
- Welds 57,7 % ($\sigma_{Ed} = 239.9$ MPa $\leq \sigma_{Rd} = 416$ MPa)
- Concrete block 83,0 % ($\sigma = 33{,}4$ MPa $\leq f_{jd} = 40$ MPa)
- Secant rotational stiffness $S_{js} = 7{,}4 \frac{\text{MNm}}{\text{rad}}$