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INFLUENCE OF ANCHOR BOLTS ON STRESSES IN BASE PLATES

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Key words: *base plate, anchor bolt, stress, БДС EN 1993-1-8*

ABSTRACT

Base plates of steel columns, as their name implies, “work” on bending. Their thickness depend on the values of the normal stresses in concrete below and / or tensile forces of the anchor bolts.

In order to mount the steel column on a design level, often beneath the base plates are placed nuts. As a result of placing the nuts under base plate, the anchor bolts can bear and transmit to the foundation compressive forces.

When determines tensile forces in anchors, standard БДС EN 1993-1-8 considers different distributions of forces between the base plate and its support. But in the standard is not specified case of transmission of compression through the anchor bolt. This causes some structural engineers not to put nuts beneath the base plates and instead to use levelling wood pieces during mounting.

With present study the author attempted to take into account the influence of compressed anchor bolts on stresses in the base plates.

1. Introduction

For mounting of steel structure, often nuts are put under the base plates, see fig. 1. With rotation they can move the column by its axis up and down. When the nuts are placed below the base plate, anchor bolts can bear and transfer compressive efforts to the foundation.

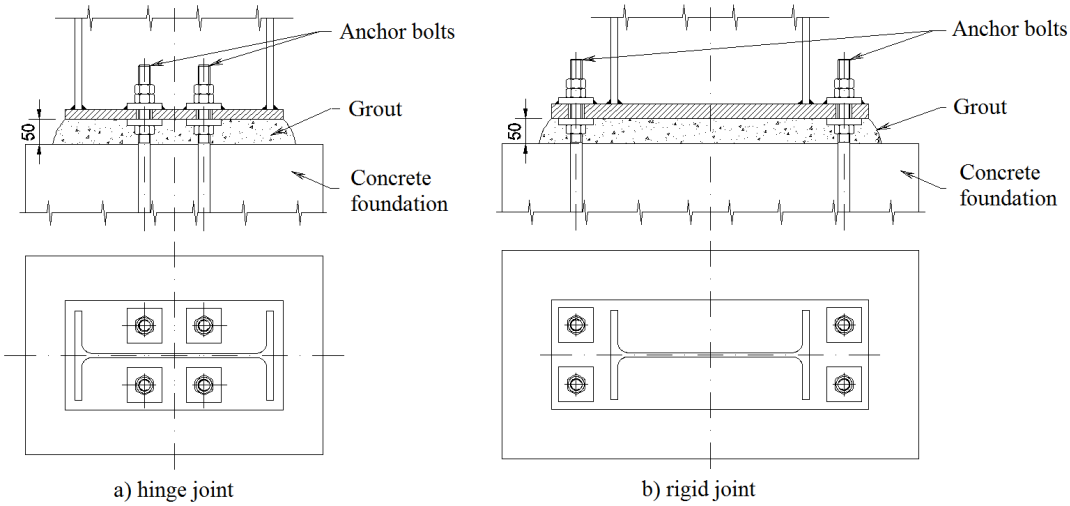

Fig. 1. Details of the connection of the steel column to the foundation

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In order to determine the tensile forces in the anchor bolts, standard БДС EN 1993-1-8 [2] considers various distribution of the efforts between base plate and its support, depending on what dominates - axial force N_{Ed} or bending moment M_{Ed}, see fig. 2.

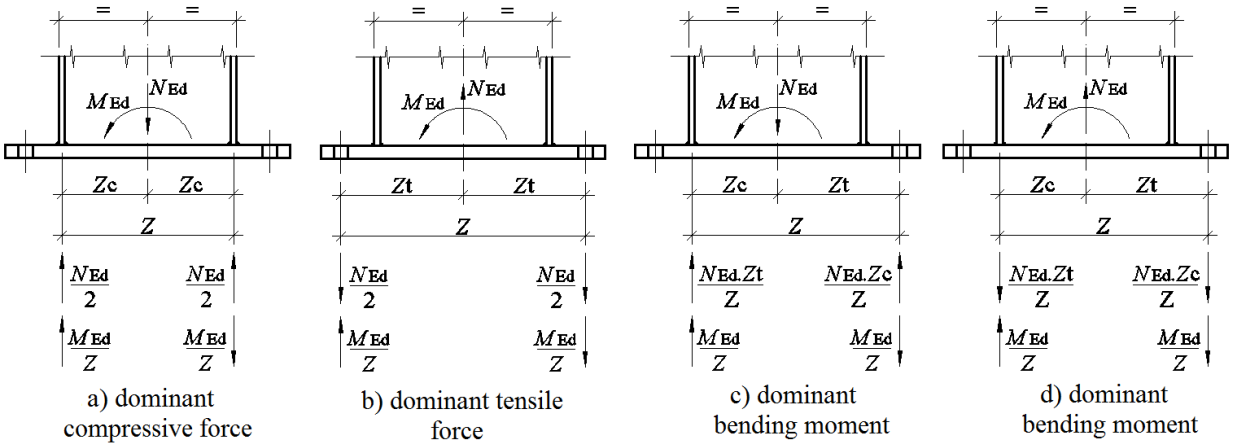


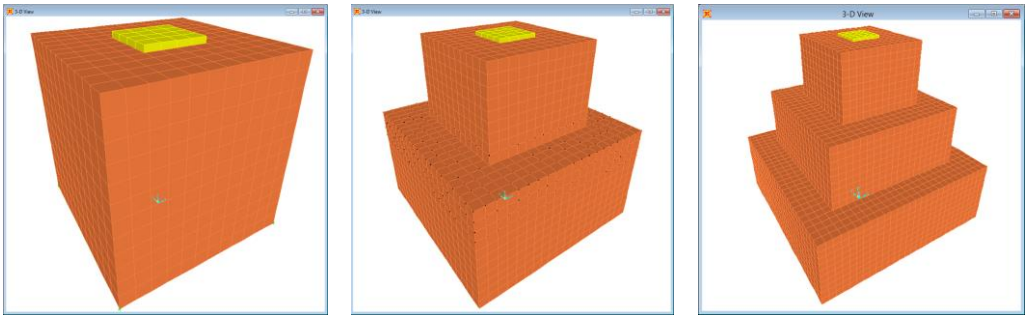
Fig. 2. Determination of the forces between the base plate and foundation.

Unfortunately, in the scheme on fig. 2 was not shown a case of transmitting compressive forces through anchor bolts. This causes some structural engineers not to put nuts beneath the base plates and instead to use levelling wood pieces during mounting.

To avoid blank speech and blind follow-up of foreign authorities, the author conducted a numerical study in which he attempted to accounts the influence of the compressed anchor bolts on the stresses in the base plates.

2. Researching model

Using software package SAP 2000 [5] were created numerical models of six concrete foundations with different dimensions, see fig. 3. A steel plate is placed on a top of every one, subjected to vertical compressive forces. In the half of the models, under the plate is simulated an anchor bolt, which reach to main plane of the foundation. Position of bolts - in the middle of the base plates, see fig. 4.

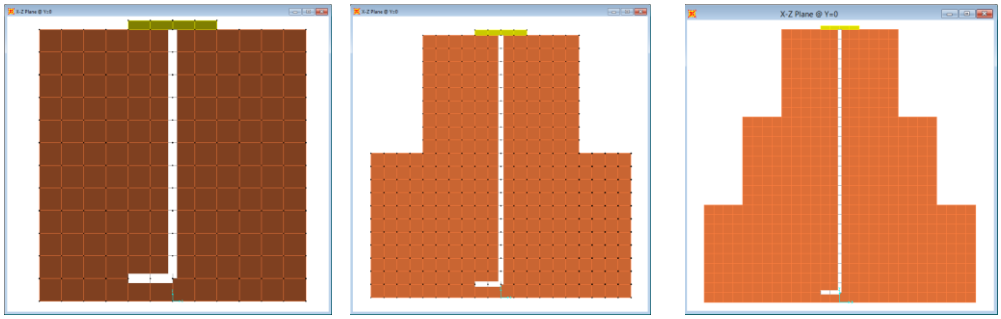


a) foundation 60x60x60 cm | b) foundation 100x100x100 cm | c) foundation 140x140x140 cm

Fig. 3. Models of concrete foundations

The bodies of the foundations are modelled through solid elements with cubic shape, which edge is 50 mm. As a material is used concrete class C20/25. Its mechanical characteristics are determined according to standard БДС EN 1992-1-1 [1].

The anchor bolts are modelled through frame elements which have common joints with the volume (solid) elements. The used steel has class S235 with mechanical properties according to the standard БДС EN 10025-2:2005 [3].



a) in foundation 60x60x60 cm | b) in foundation 100x100x100 cm | c) in foundation 140x140x140 cm

Fig. 4. Position of the anchor bolts in the foundations

The base plates have dimensions in plane 200x200 mm. They are positioned in the middle of the foundations. The used material is steel S235. The plates are loaded with vertical compressive force N_c = 1 600 kN, applied to their upper surface.

Deformability of the earth bed under the foundation is simulated by springs in which the dependence "force – movement' is linear.

3. Results

The influence of the anchor bolts is searched as a difference in shortening of the foundations, in their middle part. The idea is that if there is a significant difference in the shortenings, the contribution of the compressed anchors should be taken into consideration. If there is not a difference or it is inconsistent, compressed anchor bolts do not have an influence on the base plate and vertical pressure will be transferred through grout below.

3.1. Foundation with dimensions 60x60x60 cm by concrete C20/25

a) base plate with thickness t = 20 mm. Anchor bolt M20

movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M20	without anchor	anchor M20	without anchor	anchor M20	Without anchor	anchor M20
Under the base plate	22.25	22.24	11.14	11.13	7.43	7.43	5.58	5.58
In the main plane	22.22	22.22	11.11	11.11	7.41	7.41	5.56	5.56
shortening	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02

b) base plate with thickness t = 28 mm. Anchor bolt M30

movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30
Under the base plate	22.25	22.24	11.13	11.13	7.43	7.43	5.58	5.58
In the main plane	22.22	22.22	11.11	11.11	7.41	7.41	5.56	5.56
shortening	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02

3.2. Foundation with dimensions 100x100x100 cm by concrete C20/25

a) base plate with thickness t = 20 mm. Anchor bolt M20

Movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M20	without anchor	anchor M20	without anchor	anchor M20	without anchor	anchor M20
Under the base plate	8.03	8.03	4.03	4.03	2.69	2.69	2.03	2.03
In the main plane	8	8	4	4	2.67	2.67	2	2
shortening	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03

b) base plate with thickness t = 28 mm. Anchor bolt M30

movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30
Under the base plate	8.03	8.02	4.03	4.02	2.69	2.69	2.03	2.02
In the main plane	8	8	4	4	2.67	2.67	2	2
shortening	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.02

3.3. Foundation with dimensions 140x140x140 cm by concrete C20/25

a) base plate with thickness t = 20 mm. Anchor bolt M20

movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M20	without anchor	anchor M20	without anchor	anchor M20	without anchor	anchor M20
Under the base plate	4.11	4.11	2.07	2.07	1.39	1.39	1.05	1.05
In the main plane	4.08	4.08	2.04	2.04	1.36	1.36	1.02	1.02
shortening	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

b) base plate with thickness t = 28 mm. Anchor Bolt M30

movement, cm	Winkler's coefficient K_b, MN/m^3							
	20		40		60		80	
	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30	without anchor	anchor M30
Under the base plate	4.11	4.11	2.07	2.07	1.39	1.38	1.05	1.04
In the main plane	4.08	4.08	2.04	2.04	1.36	1.36	1.02	1.02
shortening	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02

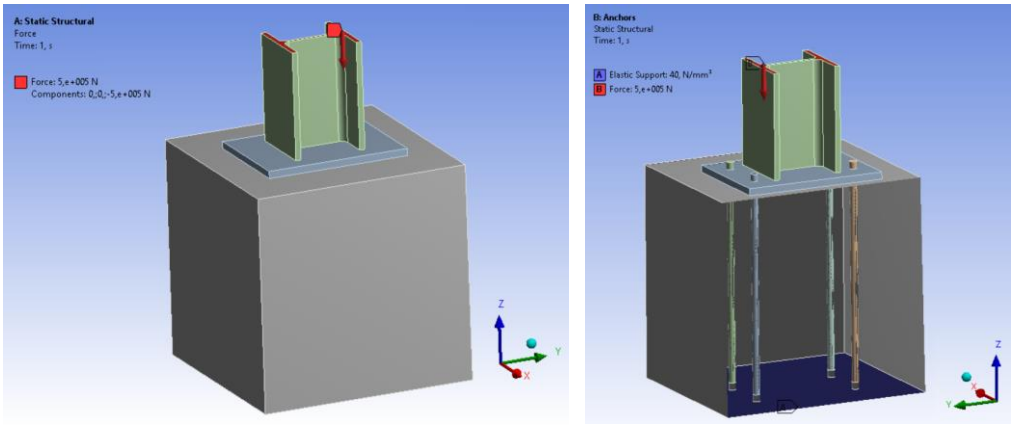
The above mentioned results show that the difference of shortening of the foundations with or without anchor bolts due to compressive force N_c = 1 600 kN is in the border of 0.1 mm, in other words - too small. Obviously bigger part of the pressure force is transferred to the foundations through the grout under the base, not through the anchor.

In order to verify the accounted by SAP 2000 results and based on them conclusions, the author is created 2 numerical models using software ANSYS [4]. They simulate "stepping" of steel column HEB 200, having a base plate with thickness t = 20 mm, on concrete foundation with dimensions 60x60x60 cm. In the first model there are not anchor bolts, in the second - 4 steel bolts with diameter Ø20 mm are used, see fig. 5.

The column is loaded with axial compressive force with intensity N_c = 500 kN.

For the column HEB 200, base plate with thickness t = 20 mm and anchor bolts Ø20 mm is used steel S235. The foundations are made from concrete class C20/25.

The connection between base plate and foundation is simulated on such a way that it can transfer only pressure.



а) without anchor bolts б) with anchor bolts Ø20

Fig. 5. Numerical models with ANSYS

The susceptibility of the earth bed under the foundation is simulated through springs with stiffness 40 MN/m^3 in which the dependency "force –movement" is linear.

The distribution of the equivalent stresses in the base plates, determined by von Mises (4th strength hypothesis), is shown on fig. 6 ÷ fig. 9.

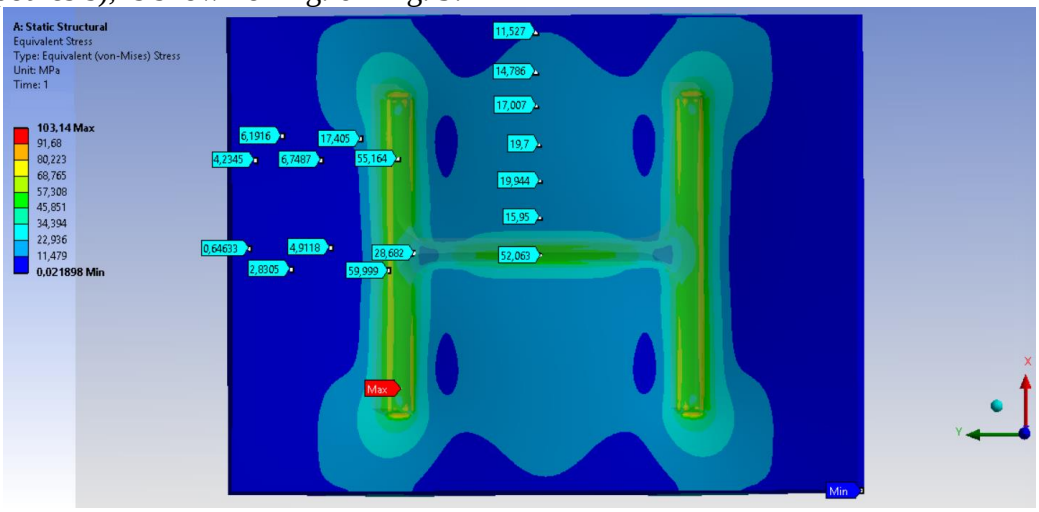


Fig. 6. Equivalent normal stresses on the upper surface of the base plate without anchor bolts

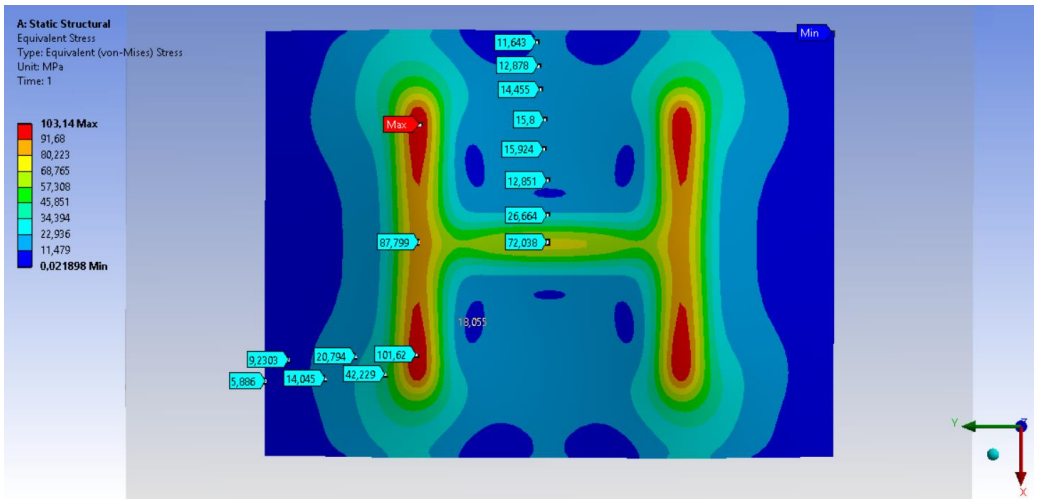


Fig. 7. Equivalent normal stresses on the inferior surface of the base plate without anchor bolts

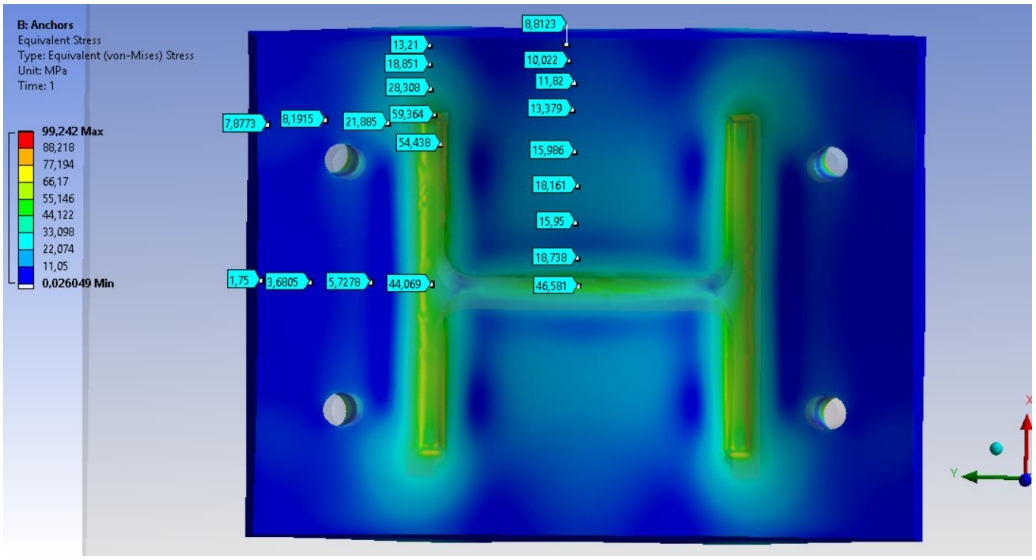


Fig. 8. Equivalent normal stresses on the upper surface of the base plate with anchor bolts

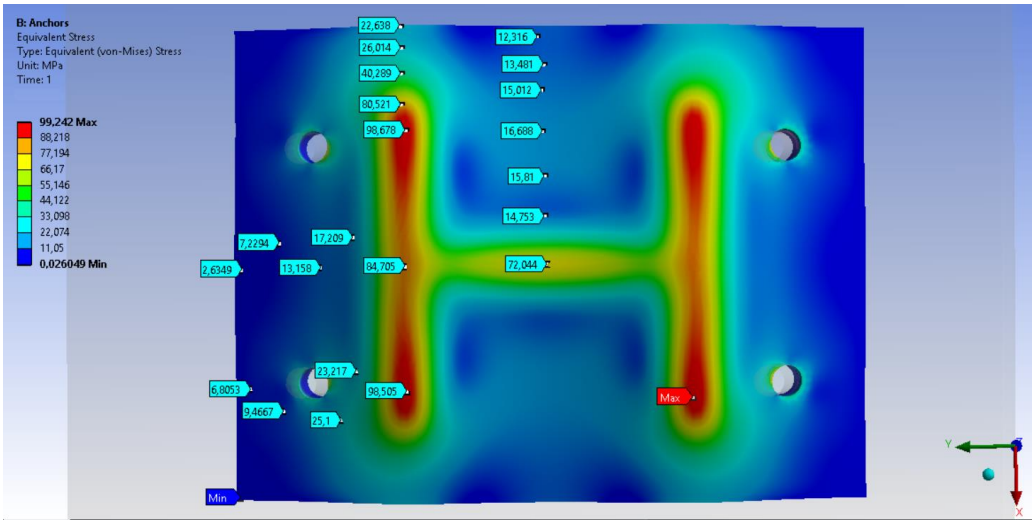


Fig. 9. Equivalent normal stresses on the inferior surface of the base plate with anchor bolts

In the both cases maximum values of the stresses are measured on the inferior surface of the base plates, under the flanges of columns. In base plate without anchors $\sigma_{eq,max}$ = 103.14 MPa, when the base has anchors Ø20 - $\sigma_{eq,max}$ = 99.24 MPa. In this particular case the difference is 3.9 %.

4. Conclusions

From the above mentioned numerical research we can do the following conclusions:

a) anchor bolts, which bear pressure, have an influence on shortening of the foundations, respectively on the forces in the steel base plate;

b) the differences in the shortening of most used foundations, with concrete class C20/25, with or without anchor bolts, do not exceed 0.1 mm, which is negligible according to the author. Obviously the considerable part of the compressive forces is transferred to the foundation through grout under the base plate, not by anchor bolts;

c) the difference in the measured equivalent normal stresses in the base plates with or without anchor bolts is not large. Even the stresses are bigger in the base plates without anchors.

Hence the methodology in the standard БДС EN 1993-1-8 [2] can be used to determine the tensile forces in the anchor bolts, even when mounting nuts are placed under the base plate. Which is confirmed by many built-up buildings and facilities that have fixing nuts under the base plates, see fig. 10. And which obviously are not in the emergency condition.

Fig. 10. Anchor bolts with nuts under the base plate. Execution.

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