FACULTY OF SCIENCE AND TECHNOLOGY

University of Stavanger

SUBJECT: **BYG 200 Steel Structures (BYG 200 Stålkonstruksjoner)**

DATE: **February 19, 2014**

DURATION: **4 hours**

AID: Norsk Standard NS-EN 1993-1-1:2005+NA:2008, Norsk Standard NS-1993-1-8: 2005+NA:2009, Norsk Standard NS-EN 1993-1-5:2006+NA:2009, Norsk Standard NS-EN 1993-1-9:2005+NA:2010, Steel Profile and Formula book "Stålkonstrukjoner", Authorized calculator.

THE EXAMINATION PAPER CONSISTS OF 4 QUESTIONS AND 1 APPENDIX ON 6 PAGES.

REMARKS: **All** the **Four** questions carry **equal marks** and answer **all** the questions.

Question (1)

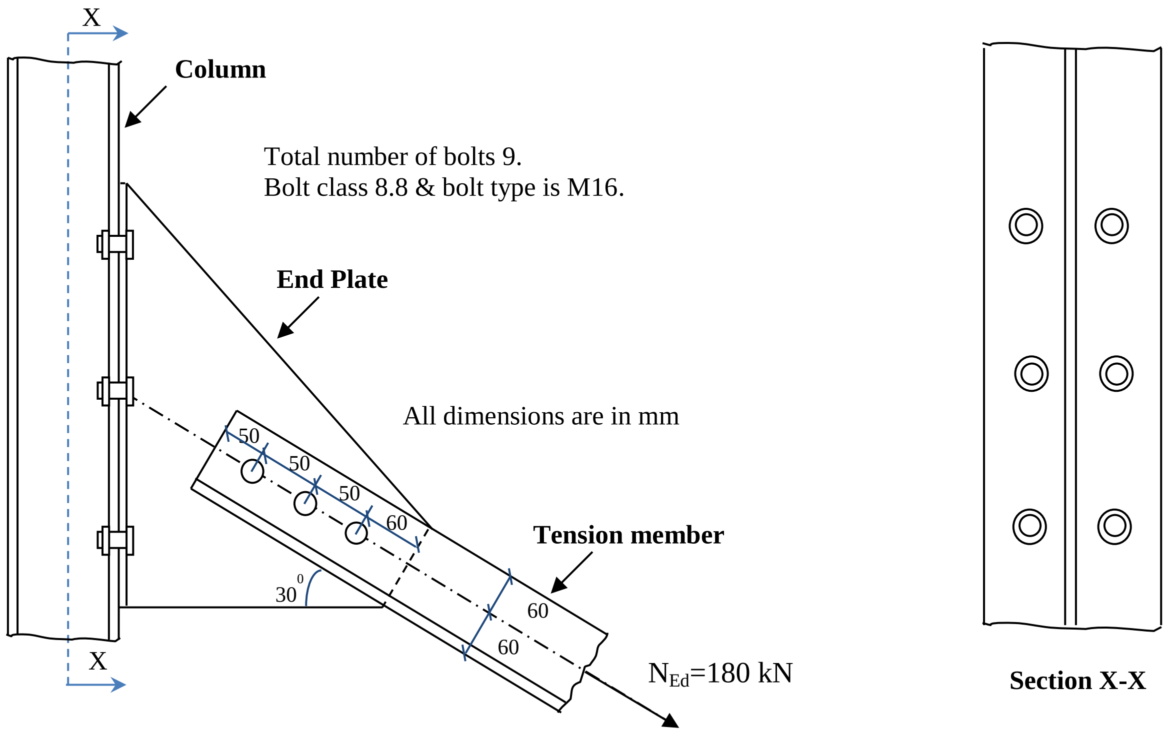
A tension member is connected to a flange of a column through an end plate as shown in Figure 1. The tension member is subjected to a design tensile force (N_{Ed}) of 180 kN. The cross section of the tension member is an unequal angle L 120×80×10 (UA Table 1.11 of "STÅLKONSTRUKJONER") of S355 steel grade. The 9 numbers of ordinary bolts are used to connect both tension member and flange to the end plate as shown in Figure 1. The shear planes of bolts are passing through **threaded (gjenget)** portions. The type of bolts is M16 (i.e. bolt diameters is 18 mm) and class of bolts is 8.8 (i.e. Skruer 8.8).

(a). Check the suitability of **tension member** (i.e. can the tension members withstand the design load). Refer Appendix A in page 6 for necessary formulae and guidelines .

(12 Marks)

(b). Check the suitability of the **bolts** (i.e. can the bolts withstand above loading).

(13 Marks)



All dimensions are in millimeters

Figure 1

Question (2)

A compression member is concentrically fixed supported at both A and B ends while allowing to slide only in vertical direction at the B end (i.e. fixed ended compression member) as shown Figure 2. The length of the member is 6 m. The member is subjected to a design axial compressive load of 1000 kN.

(a). If the cross section of the member shown in Figure 2 is HE140B (HE-B Table 1.3 of "STÅLKONSTRUKJONER") of steel grade S275.

(i). Confirm that the column is not suitable (i.e. column cannot withstand the above loadings). **(8 Marks)**

(ii). If both A and B ends of the member are changed to simply supported ends (i.e. pin ended compression member), do you think that the member can carry the above loadings. State the logical reasons for your answer without any calculation. **(3 Marks)**

(b). If the cross section of the member shown in Figure 2 is HE900B (HE-B Table 1.3 of "STÅLKONSTRUKJONER") of steel grade S355.

(i). Confirm the cross section of the member is in Class 4 and determine the effective cross sectional area (A_{eff}). **(6 Marks)**

(ii). Determine the design compressive resistance ($N_{c,Rd}$) of the member and check the suitability of the column against cross sectional yielding (i.e. can the column withstand the axial load without cross sectional yielding). **(3 Marks)**

(iii). Determine the design buckling resistance ($N_{b,Rd}$) of the member and check the suitability of the column against overall flexural buckling (i.e. can the column withstand the axial load without overall flexural buckling). **(5 Marks)**

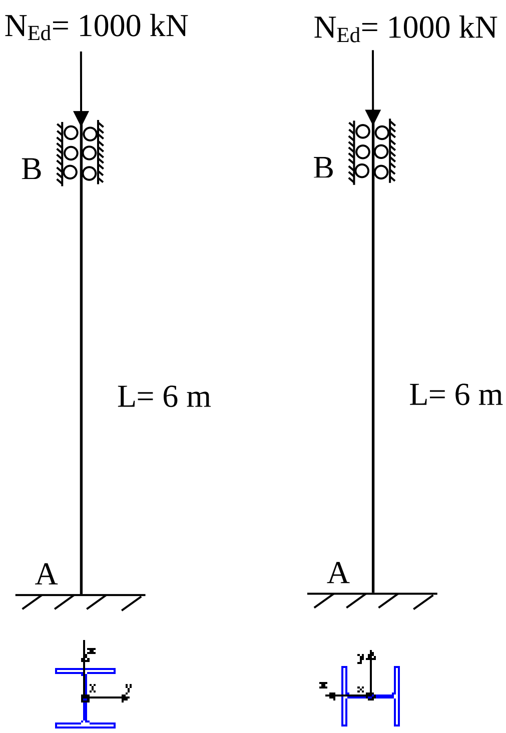


Figure 2

Question (3)

(a). A beam is subjected to a uniformly distributed dead load (Q_d) of 35 kN/m and an imposed load (Q_i) of 50 kN/m as shown in Figure 3(a). Length of the beam is 5 m and simply supported at both ends. Both supports are prevented from twist rotations in addition to its usual translational restraints. The top flange of beam has been sufficiently laterally braced against lateral torsional buckling.

(i). Design a suitable hot rolled universal beam (IPE Table 1.1 of "STÅLKONSTRKJONER") of steel grade S355 for this beam by considering Ultimate Limit State (ULS). **(10 Marks)**

(ii). Check that this beam satisfies the Serviceability Limit State (SLS) which governs the deflection limit for appearance (i.e. Length/200). **(3 Marks)**

(b). A 3 m height column is subjected to a design axial compressive force of 600 kN and a design end moment of 200 kNm about *y-y* axis at the top end as shown in Figure 3(b). The column is fixed at the bottom and column section is HE300B (HE-B Table 1.3 of "STÅLKONSTRUKJONER") of steel grade S355.

(i). Confirm the cross section of the column is in Class 1. **(3 Marks)**

(ii). Check the column for cross sectional yielding (i.e. whether column can withstand above loadings without cross sectional yielding). **(9 Marks)**

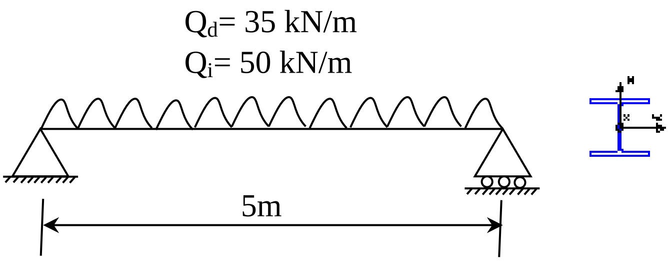


Figure 3 (a)

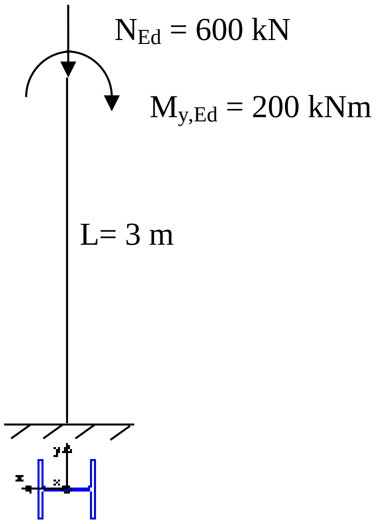


Figure 3 (b)

Question (4)

(a). A cantilever member is subjected to uniformly distributed design torque (T_o) 1 kNm/m as shown in Figure 4 (a). The length of the member is 3 m and cross section is IPE 500 (Table 1.1 of "STÅLKONSTRKJONER") of S355 steel grade. Assume that the Torsional Rigidity (GI_T) is negligible compared to Warping Rigidity (EC_w) of the member (i.e. $EC_w >> GI_T$ and hence effects of St.Venant torsion can be neglected). The twist rotation and warping are prevented by the left end support while other end is free to warp as shown in Figure 4 (a).

(i). Determine the maximum values for warping normal stress ($\sigma_{w,max}$) and warping shear stress ($\tau_{w,max}$). **(11 Marks)**

(ii). Check the suitability of the beam (i.e. can the beam withstand the design torque) in Ultimate Limit State (ULS). **(2 Marks)**

(b). The Figure 4 (b) shows a deck of a railway bridge. The cross girder AB is an I beam and it mainly subjected bending stresses. The cross girder is rigidly connected to other rail barer and main girder by **riveted joints** (detailed category 71). The static structural analysis reveals that the bottom flange of *AB* cross girder is subjected to variable amplitude random stress history and obtained critical (i.e. highest value) stress history for a single train (i.e. rail traffic) is shown in Figure 4 (b). It is also assumed that 10 numbers of similar trains are only passing over the bridge during a day. The dynamic factor of this cross girder is 1,2. Assume the assessment method of this bridge (i.e. safety concept) as safe life (i.e. no inspection is doing) and high consequence (i.e. important member). Determine the fatigue life of the AB cross girder. **(12 Marks)**

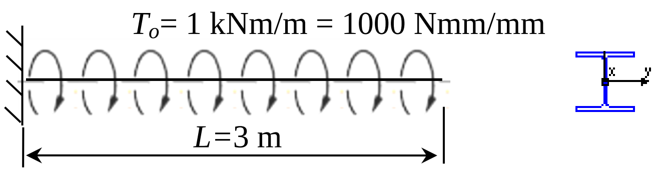


Figure 4 (a)

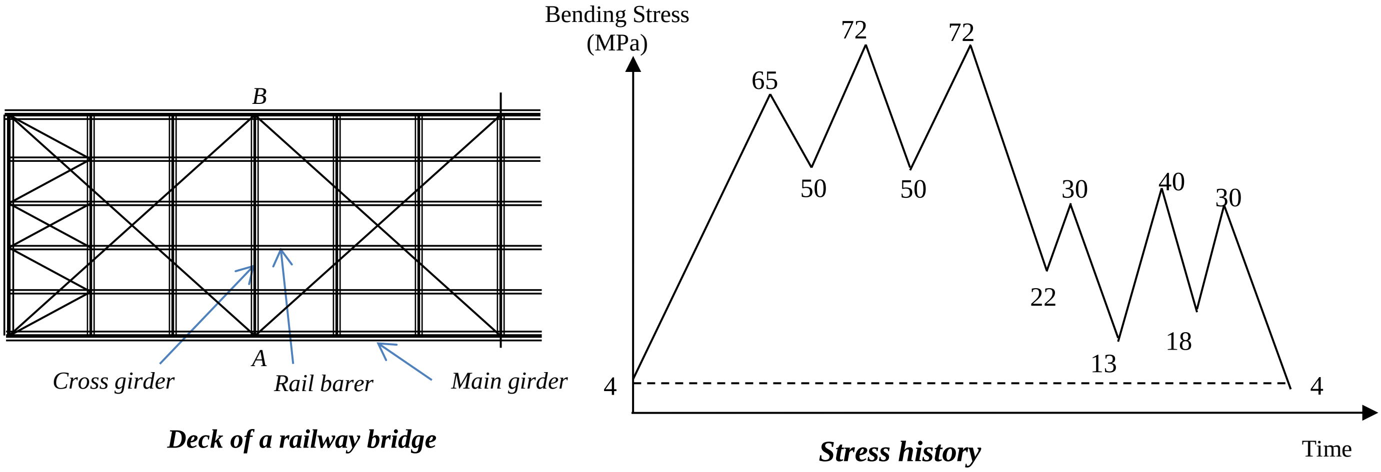


Figure 4 (b)

Appendix-A: (Extracted From EN 1993-1-8: 2005)

3.10.3 Angles connected by one leg and other unsymmetrically connected members in tension

(1) The eccentricity in joints, see 2.7(1), and the effects of the spacing and edge distances of the bolts, shall be taken into account in determining the design resistance of:

- unsymmetrical members;
- symmetrical members that are connected unsymmetrically, such as angles connected by one leg.

(2) A single angle in tension connected by a single row of bolts in one leg, see Figure 3.9, may be treated as concentrically loaded over an effective net section for which the design ultimate resistance should be determined as follows:

with 1 bolt:
$$N_{u,Rd} = \frac{2,0(e_2 - 0,5d_0)t\ f_u}{\gamma_{M2}} \quad \text{... (3.11)}$$

with 2 bolts:
$$N_{u,Rd} = \frac{\beta_2\ A_{net}\ f_u}{\gamma_{M2}} \quad \text{... (3.12)}$$

with 3 or more bolts:
$$N_{u,Rd} = \frac{\beta_3\ A_{net}\ f_u}{\gamma_{M2}} \quad \text{... (3.13)}$$

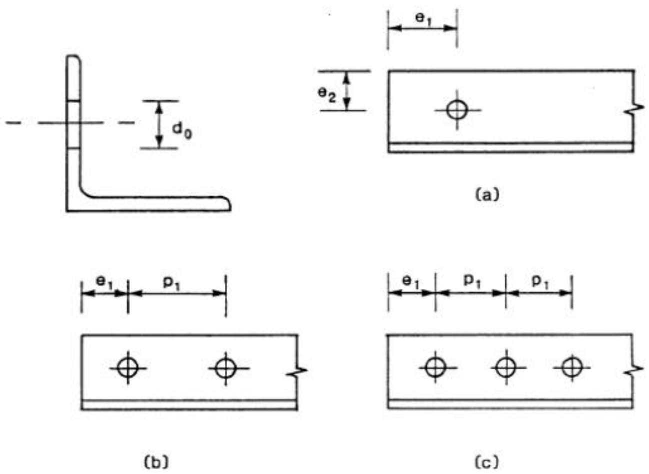
where:

β_2 and β_3 are reduction factors dependent on the pitch p_1 as given in Table 3.8. For intermediate values of p_1 the value of β may be determined by linear interpolation;

A_{net} is the net area of the angle. For an unequal-leg angle connected by its smaller leg, A_{net} should be taken as equal to the net section area of an equivalent equal-leg angle of leg size equal to that of the smaller leg.

Table 3.8: Reduction factors β_2 and β_3

Pitch	p_1	$\leq 2,5\ d_o$	$\geq 5,0\ d_o$
2 bolts	β_2	0,4	0,7
3 bolts or more	β_3	0,5	0,7



a) 1 bolt

b) 2 bolts

c) 3 bolts

Figure 3.9: Angles connected by one leg