Comparison of the design of the crane runway according to former Czech national standards and currently valid Eurocodes

MILAN PILGR & ONDREJ PESEK
Department of Metal and Timber Structures
Brno University of Technology, Faculty of Civil Engineering
Veveri 331/95, 602 00 Brno
THE CZECH REPUBLIC
pilgr.m@fce.vutbr.cz pesek.o@fce.vutbr.cz http://www.fce.vutbr.cz

Abstract: - This paper is focused on the load and the design of the crane runway inside a single-storey building. Two electric heavy overhead travelling cranes running on the crane supporting structure. The crane runway girder consists of the (vertical) crane runway beam, the lattice surge girder and the sloping truss. Analyzes of the vertical actions, the lateral surges and the braking forces according to CSN 73 0035 and Eurocode No. 1 are compared in this paper. Verifications of the pure resistance of the cross-sections, the lateral-torsional buckling resistance of the beam, the plate buckling resistance of the slender walls, the resistance of the web to flange welds, the deflections and the fatigue strength according to CSN 73 1401 and Eurocode No. 3 are compared in this paper too.

Key-Words: - steel structure, crane supporting structure, load, design, CSN, Eurocode

1 Introduction

The Czech national standards CSN for design of load-carrying structures were violated in April 2010. The CSN standards were replaced by the final drafts of Eurocodes. Problems of design of crane supporting structures have undergone great changes. The changes consist mainly of different calculation methods. Different values of effects of loads, resistances, reliability reserve and dimensions of load carrying members of crane runways are a consequence of those changes. The presented paper is focused on the differences of values of the mentioned quantities, which are set according to former Czech national standards (valid before 1995) and final drafts of Eurocodes (valid from 2010), see the table 1. Two electric heavy overhead travelling cranes running on the crane supporting structure. The crane runway girder consists of the (vertical) crane runway beam, the lattice surge girder and the sloping truss.

Note that currently apply two sets of standards for bridge cranes, see the table 2 – but the currently valid Eurocodes refer to the standards shown in the right column of the table only.

2 Arrangement of crane runway

We assume that the crane runway girder consists of the (vertical) crane runway beam, the lattice surge girder and the sloping truss. It is simply supported beam, which is supported by main columns of the building – the spacing of the main columns is 12,0 m. The cross-section of the vertical crane runway beam is a singly-symmetric I with the upper flange thicker than the lower flange. The dimensions of the cross-section are: the high h = 1200 mm, the breadth b = 400 mm, the web thickness t_w = 12 mm, the upper flange thickness t_{f1} = 30 mm, the lower flange thickness t_{f2} = 25 mm and the effective thickness of the web to flange welds a = 8 mm. The surge girder consists of modified Warren truss – the first chord is identical with the upper chord of the vertical crane runway beam, the second chord consists of an angel couple. The cross-section of web members is an equal leg angel. The high of the truss of the surge girder is h_{sg} = 1,2 m. The outer chord of the lattice surge girder is supported by the sloping truss – the distance of the supports is equal 3,0 m. It is a triangular close structural system, which consists of the (vertical) crane runway beam, the lattice surge girder and the sloping truss, and which is cinematically determinate, see the figure 1. In this case two electric overhead travelling cranes running on the crane supporting structure in singly-storey building with span 24,0 m – crane parameters are specficated in CSN 27 0200 – the first crane has the rated capacity 50/12,5 t, the second crane has the rated capacity 32/8 t. The class of the fatigue actions of both cranes is No. II (according to CSN 27 0103) or the S_5 (according to CSN EN 13001-2+A3). The

ISBN: 978-1-61804-137-1

hoisting class of appliance of both cranes is the *b* (according to CSN 27 0103) or the HC2 (according to CSN EN 15011). We will consider the possibility of a work of coupled cranes. In the following we give a comparison of checks of an intermediate span of the crane runway girder. The steel grade of the parent material is No. 37 (according to CSN 73 1401) or the S 235 (according to CSN EN 1993-1-1).

Table 1 – Overview of CSN and EC standards for actions and design of crane supporting structures

Č.	Problems	References to the provisions of the former standards[1])	References to the provisions of the currently valid standards
Actions on the crane supporting structure			
1	The self-weight of the crane	CSN 73 0035 [19], section III	CSN EN 1991-1-1 [20], section 5
2	The vertical actions of the wheels	CSN 73 0035 [19], section IV.C	CSN EN 1991-3 [21], clause 2.6
3	The lateral surges	CSN 73 0035 [19], section IV.C	CSN EN 1991-3 [21], clause 2.7
4	The imposed loads on the walkways	CSN 73 0035 [19], section IV.A	CSN EN 1991-3 [21], clause 2.9
5	The fatigue loads	CSN 73 0035 [19], section IV.C	CSN EN 1991-3 [21], clause 2.12
Design of the crane supporting structure			
6	The pure resistance of the cross-section	CSN 73 1401 [22], section V	CSN EN 1993-1-1 [23], clause 6.2
7	The lateral-torsional buckling resistance of the beam	CSN 73 1401 [22], section VI	CSN EN 1993-1-1 [23], clause 6.3
8	The plate buckling resistance of the walls	CSN 73 1401 [22], section VII	CSN EN 1993-1-5 [24]
9	The resistance of the web to flange welds	CSN 73 1401 [22], section VIII	CSN EN 1993-1-8 [25], section 4
10	The deflections	CSN 73 1401 [22], section XI	CSN EN 1993-6 [27], section 7
11	The fatigue strength	CSN 73 1401 [22], section IX	CSN EN 1993-1-9 [26]
[1]) CSN 73 0035 was repealed 1st April 2010, CSN 73 1401 was repealed 1st April 1995.			

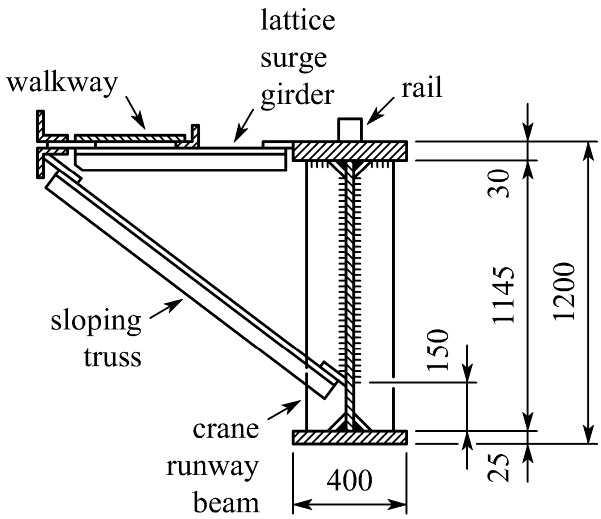

Fig. 1 – The cross-section of the crane runway girder

ISBN: 978-1-61804-137-1

3 Values of loads

Values of actions induced by cranes, including the static and equivalent dynamic component of a crane action, are given in Table 3. The values are calculated according to CSN 73 0035 and CSN EN 1991-3.

4 Reliability reserves of salient limit states

4.1 The pure resistance of the cross-sections

The results of the calculations of the checks according to CSN 73 1401 show that the most unfavourable load occurs in the extreme fibres of the upper flange namely a) due to the maximum vertical bending moment in the cross-section of the vertical crane runway beam due to the vertical actions, b) due to the compressive axial force in the upper chord of the vertical crane runway beam due to a horizontal flexure of the lattice surge girder due to the (transverse) forces caused by skewing of the crane, c) due to the horizontal bending in the upper chord of the vertical crane runway beam due to mimostycny action of the (transverse) force caused by skewing of the crane. The ratio of effects of load and resistance E_d / R_d is 0,87.

The results of the calculations of the checks according to CSN EN 1993-1-1 show that the most unfavourable load occurs in the edge of the web below the upper flange namely a) due to the global shear stress due to the (vertical) shear force, b) to d) due to the local compressive stress, the local shear stress and the local bending stress due to the concentrated transverse force – wheel load. The ratio of effects of load and resistance E_d / R_d is 1,80.

Table 2 – Overview of the current standards for bridge cranes and crane supporting structures

Problems	Existing standards	Newly introduced standards
Bridge cranes		
Terminology of branch of cranes	CSN 27 0005	CSN ISO 4306-1
Projection and construction of cranes	CSN 27 0140[1])	CSN EN 15011
Actions on the load-carrying structures of cranes	CSN ISO 8686-1	CSN EN 13001-2+A3
Design of the steel structures of cranes	CSN 27 0103	CSN P CEN/TS 13001-3-1
Dimensions, speeds of motions, values of actions on the crane supporting structure	CSN 27 0200[2])	–
Crane supporting structures		
Requirements for structural clearance of crane	CSN 73 5130	CSN EN 15011
Tolerances of dimensions of crane supporting structures	CSN 73 5130	CSN ISO 12488-1
Access routes, admission to the crane station	CSN 73 5130	ISO 11660-5[3])
Load-carrying structure of the crane runway	see table 1, the right column	
[1]) Repealed 1st August 2011. [2]) Repealed 1st November 2006. [3]) Not yet introduced.		

ISBN: 978-1-61804-137-1

4.2 The lateral-torsional buckling resistance of the beam

If the buckling length of the upper chord of the vertical crane runway beam is L_c = 1500 mm (equal to the distance between the joints of the lattice surge girder) than the beam does not susceptible to a lateral buckling. They are the results of the calculations of the checks both according to CSN 73 1401 and according to CSN EN 1993-1-1.

4.3 The plate buckling resistance of the slender walls

The results of the calculations of the checks both according to CSN 73 1401 and according to CSN EN 1993-1-5 show that the most unfavourable load occurs in the end web panel namely a) due to the maximum shear stress, b) due to the concentrated transverse force – wheel load. The ratio of effects of load and resistance E_d / R_d is 1,00 according to CSN 73 1401 or 0,66 according to CSN EN 1993-1-5.

4.4 The resistance of the web to flange welds

The results of the calculations of the checks according to CSN 73 1401 show that the most unfavourable load occurs a) due to the maximum bending moment, b) due to the corresponding shear force, c) due to the concentrated transverse force – wheel load. The ratio of effects of load and resistance E_d / R_d is 0,88.

The results of the calculations of the checks according to CSN EN 1993-1-8 show that the most unfavourable load occurs a) due to the maximum shear force, b) due to the concentrated transverse force – wheel load. The ratio of effects of load and resistance E_d / R_d is 0,53.

4.5 The deflection

The results of the analysis both according to CSN standards and according to Eurocodes give the maximum horizontal deflection at mid-span for which holds the ratio of effect of load and serviceability criterion E_d / C_d = 0,67 according to CSN 73 1401 or E_d / C_d = 0,68 according to CSN EN 1993-6.

4.6 The fatigue strength

The results of the calculations of the checks both according to CSN 73 1401 and according to CSN EN 1993-1-9 show that the most unfavourable load occurs in the web to flange welds namely due to the stress range of the vertical compressive stress due to the concentrated transverse force – wheel load. The ratio of effects of load and resistance E_d / R_d is 0,99 according to CSN 73 1401 or 1,76 according to CSN EN 1993-1-9.

5 Conclusion

If the load-carrying structure of the crane runway with chosen arrangement (fig. 1) is checked using the methods of the former Czech national standards than all reliability conditions are satisfied; if the crane supporting structure is checked using the methods of the currently valid Eurocodes than the pure resistance and the fatigue strength are unsatisfactory (see the paragraphs 4.1 and 4.6). A reliable load-carrying structure of the crane runway should have the following dimensions: we enlarge the web thickness width t_w from 12 to 15 mm, the upper flange thickness t_{f1} from 30 to 40 mm, the lower flange thickness t_{f2} from 25 to 32 mm and the effective thickness of the web to flange welds below the upper flange a from 8 to 16 mm. The total mass of the crane runway girder is greater by cca 30 %.

Table 3 – Overview of the values of the actions induced by the cranes in kN set according to CSN and EC

Action			The maximum vertical action of the wheel	The longitudinal braking force	The transverse braking force	The transverse force caused by skewing of the crane
of the crane 50/12,5 t	according to CSN	characteristic design	362 543	36,2 39,8	13,6 14,9	55,3 60,8
	according to EC	characteristic design	367 554	19,3 39,1	15,3 20,7	110 149
of the crane 32/8 t	according to CSN	characteristic design	253 364	25,3 27,8	9,58 10,5	48,1 52,9
	according to EC	characteristic design	249 380	14,0 28,4	10,1 13,6	74,7 101

ISBN: 978-1-61804-137-1

Acknowledgements:
This research has been supported by project of GACR No. P105/12/0314, by research programme of MSMT No. MSM 0021630519, by project of specific university research No. FAST-12/1786 and by education programme of OPVK No. CZ.1.07/2.2. 00/15.0426.

References:

[1] PILGR, M. *Kovove konstrukce. Vypocet jerabove drahy pro mostove jeraby podle CSN EN 1991-3 a CSN EN 1993-6*. Brno: CERM, 2012, 202 pp. ISBN 978-80-7204-807-6.

[2] PILGR, M. Porovnani vypoctu jerabove drahy pro mostove jeraby podle puvodnich ceskych norem a soucasne platnych eurokodu. In *Proceedings of the IX. International Scientific Conference FCE TUKE* [CD-ROM]. Kosice: TU, 2012, 6 pp. ISBN 978-80-553-0905-7.

[3] MELCHER, J. and STRAKA, B. *Kovove konstrukce. Konstrukce prumyslovych budov*. Praha: SNTL, 1985, 218 pp.

[4] FERJENCIK, P., SCHUN, J., MELCHER, J., VORISEK, V. and CHLADNY, E. *Navrhovanie ocelovych konstrukcii. 1. cast*. Bratislava: Alfa, 1986, 616 pp.

[5] KARMAZINOVA, M., PILGR, M. and MELCHER, J. Methods based on the approaches of the design assisted by testing applied for the determination of material properties. In *Mathematical Models and Methods in Modern Science – Proceedings of the NAUN / IEEEAM International Conferences „MMES '11", „DEEE '11", „COMATIA '11"*. Puerto de la Cruz: WSEAS Press, 2011, pp. 25–30. ISBN 978-1-61804-055-8.

[6] KARMAZINOVA, M. and MELCHER, J. Methods of the design assisted by testing – applicable tools for the design resistance evaluation using test results. In *Mathematical Models and Methods in Modern Science – Proceedings of the NAUN / IEEEAM International Conferences „MMES '11", „DEEE '11", „COMATIA '11"*. Puerto de la Cruz: WSEAS Press, 2011, pp. 31–36. ISBN 978-1-61804-055-8.

[7] PILGR, M. and KARMAZINOVA, M. Analysis and idealization of strain mechanism of end-plate connections. In *Mathematical Models and Methods in Modern Science – Proceedings of the NAUN / IEEEAM International Conferences „MMES '11", „DEEE '11", „COMATIA '11"*. Puerto de la Cruz: WSEAS Press, 2011, pp. 60–65. ISBN 978-1-61804-055-8.

[8] KARMAZINOVA, M., STRBA, M. and KVOCAK, V. Steel-concrete composite members using high-strength materials in building constructions – structural design, actual behaviour, application. In *Recent Researches in Engineering and Automatic Control – Proceedings of the NAUN / IEEEAM International Conferences „ECC '11", „ECME '11", „ECCIE '11", „ECCE '11"*. Puerto de la Cruz: WSEAS Press, 2011, pp. 47–52. ISBN 978-1-61804-057-2.

[9] NEUBAUEROVA, P., KARMAZINOVA, M. and BUKOVSKA, P. Strengthening timber beams using externally bonded carbon – fiber reinforced polymer. In *Recent Researches in Engineering Mechanics, Urban & Naval Transportation and Tourism – Proceedings of the WSEAS International Conferences „EMESEG '12", „UPT '12", „MN '12", „CUHT '12"*. Cambridge: WSEAS Press, 2012, pp. 31–36. ISBN 978-1-61804-071-8.

[10] HORACEK, M. and MELCHER, J. Torsion Stiffness of Thin-walled Steel Beams with Web Holes. In *Recent Researches in Engineering Mechanics, Urban & Naval Transportation and Tourism – Proceedings of the WSEAS International Conferences „EMESEG '12", „UPT '12", „MN '12", „CUHT '12"*. Cambridge: WSEAS Press, 2012, pp. 103–108. ISBN 978-1-61804-071-8.

[11] BUKOVSKA, P., KARMAZINOVA, M. and NEUBAUEROVA, P. Buckling Resistance of Steel Tubular Columns Filled by High-strength Concrete. In *Recent Researches in Engineering Mechanics, Urban & Naval Transportation and Tourism – Proceedings of the WSEAS International Conferences „EMESEG '12", „UPT '12", „MN '12", „CUHT '12"*. Cambridge: WSEAS Press, 2012, pp. 172–177. ISBN 978-1-61804-071-8.

[12] KARMAZINOVA, M., BUKOVSKA, P. and NEUBAUEROVA, P. Theoretical and experimental analysis of load-carrying capacity of steel-concrete composite beams with glass-fibre-concrete slab. In *Recent Researches in Engineering Mechanics, Urban & Naval Transportation and Tourism – Proceedings of the WSEAS International Conferences „EMESEG '12", „UPT '12", „MN '12", „CUHT '12"*. Cambridge: WSEAS Press, 2012, pp. 221–226. ISBN 978-1-61804-071-8.

[13] KARMAZINOVA, M., NEUBAUEROVA, P. and BUKOVSKA, P. Effectiveness of

strengthening steel beams using external bonded CFRP lamellas. In *Recent Researches in Engineering Mechanics, Urban & Naval Transportation and Tourism – Proceedings of the WSEAS International Conferences „EMESEG '12“, „UPT '12“, „MN '12“, „CUHT '12“*. Cambridge: WSEAS Press, 2012, pp. 243–247. ISBN 978-1-61804-071-8.

[14] HORACEK, M. and MELCHER, J. Mathematical Definitions and Experimentally Verification of the Torsion Characteristics of Perforated Steel Beams. In *Advances in Mathematical and Computational Methods – Proceedings of the 14th WSEAS International Conference „MACMESE '12“*. Sliema: WSEAS Press, 2012, pp. 91–96. ISSN 2227-4588, ISBN 978-1-61804-117-3.

[15] KARMAZINOVA, M. Design resistance of steel expansion anchors under shear loading derived using methods of design assisted by testing. In *Advances in Mathematical and Computational Methods – Proceedings of the 14th WSEAS International Conference „MACMESE '12“*. Sliema: WSEAS Press, 2012, pp. 103–108. ISSN 2227-4588, ISBN 978-1-61804-117-3.

[16] MELCHER, J. and KARMAZINOVA, M. Reliability of the Limit States Design Concept Ensuring the Safety and Efficiency of Structures. In *Advances in Mathematical and Computational Methods – Proceedings of the 14th WSEAS International Conference „MACMESE '12“*. Sliema: WSEAS Press, 2012, pp. 162–165. ISSN 2227-4588, ISBN 978-1-61804-117-3.

[17] KARMAZINOVA, M. and MELCHER, J. Verification of steel-to-concrete anchorage system reliability based on failure probability evaluation using test results. In *Advances in Mathematical and Computational Methods – Proceedings of the 14th WSEAS International Conference „MACMESE '12“*. Sliema: WSEAS Press, 2012, pp. 247–252. ISSN 2227-4588, ISBN 978-1-61804-117-3.

[18] CSN EN 1990 (73 0002) *Eurokod: Zasady navrhovani konstrukci*. Praha: CNI, 2004.

[19] CSN 73 0035 *Zatizeni stavebnich konstrukci*. Praha: UNM, 1986.

[20] CSN EN 1991-1-1 (73 0035) *Eurokod 1: Zatizeni konstrukci – Cast 1-1: Obecna zatizeni – Objemove tihy, vlastni tiha a uzitna zatizeni pozemnich staveb*. Praha: CNI, 2004.

[21] CSN EN 1991-3 (73 0035) *Eurokod 1: Zatizeni konstrukci – Cast 3: Zatizeni od jerabu a strojniho vybaveni*. Praha: CNI, 2008.

[22] CSN 73 1401 *Navrhovani ocelovych konstrukci*. Praha: UNM, 1984.

[23] CSN EN 1993-1-1 (73 1401) *Eurokod 3: Navrhovani ocelovych konstrukci – Cast 1-1: Obecna pravidla a pravidla pro pozemni stavby*. Praha: CNI, 2006.

[24] CSN EN 1993-1-5 (73 1401) *Eurokod 3: Navrhovani ocelovych konstrukci – Cast 1-5: Bouleni sten*. Praha: CNI, 2008.

[25] CSN EN 1993-1-8 (73 1401) *Eurokod 3: Navrhovani ocelovych konstrukci – Cast 1-8: Navrhovani stycniku*. Praha: CNI, 2006.

[26] CSN EN 1993-1-9 (73 1401) *Eurokod 3: Navrhovani ocelovych konstrukci – Cast 1-9: Unava*. Praha: CNI, 2006.

[27] CSN EN 1993-6 (73 1460) *Eurokod 3: Navrhovani ocelovych konstrukci – Cast 6: Jerabove drahy*. Praha: CNI, 2008.