Summary

Lots of countries have developed their own standards in the past. Nowadays, when companies work around the whole world, they have to work with lots of standards. In Europe they are busy to create European standards which are based on the national standards. In this report seven different construction standards are compared to each other by using an example case. The standards compared to each other are: EN 13001, NEN 2018/2019, FEM (Federation Europeenne de la Manutention), BS 5400, LRFD (Load Resistance Factor Design), Lloyds and the DNV (Det Norske Veritas). Most of the standards handle cranes, but BS 5400 handles bridges (bridges are mainly loaded with their own weight, and cranes are mainly loaded with the hoisted load). The LRFD handles steel structures, but also structures in which overhead cranes are traveling. EN 13001 and BS 5400 have two methods for the proof of competence. For the example case a leg of a container gantry crane is used. It is loaded with axial loads and a bending moment.

The standards EN13001, NEN 2018/2019 and the FEM have a classification in types of cranes, loads and frequencies of loads. The other standards haven't got a classification; only in BS 5400 the type of live load is classified. The "live HA load" is chosen because there the highest safety factors are present.

To compare the standards, the proof of competence is done by using the worst load combination. In most cases this is load combination 1, and in the LRFD it is load combination 2. The proofs are done as follows:
The minimum wall thickness will be calculated first according to the yield stress. The maximum applied stress due to the load combination must not be higher than the maximum applicable stress obtained by the yield stress and the appropriate safety factor. The DNV uses another additional formula for a minimum wall thickness of primary and secondary elements. The leg is assumed to be a primary element.
Then it will be checked if the wall thickness is enough for the column to withstand buckling. If not, then the wall thickness will be increased until it is high enough.
After buckling it will be checked if the column withstands fatigue. For fatigue there are two main methods: in the EN 13001, NEN 2018/2019, FEM, LRFD the maximum stress range is used, in combination with a stress spectrum factor. The proof of Lloyds is done in accordance with a national standard, the NEN 2018/2019 is chosen. BS 5400 and the DNV the fatigue damage is calculated by using two mean stress cycles. When the stress spectrum factor was obtained, the same mean stress cycles were used. Fatigue was in most cases not the critical condition (ie the wall thickness was big enough). Only in EN 13001, limit state method, fatigue was critical.
The last check was the check for local plate buckling. When a large unstiffened plate is compressed at the edges, the plate is going to buckle. To avoid that, stiffeners must be added. The number of stiffeners depends on the wall thickness (the thinner the wall, the more stiffeners are needed) and the type and magnitude of load. In most cases a reference stress σ_e is calculated, and factored with factors depending on the type of load and appropriate safety factors to get the maximum applicable stress. EN 13001 and NEN 2018/2019 refer to DIN 18800. The other standards have their own proof of plate buckling. For plate buckling every wall thickness could be enough, but to avoid that very many stiffeners are needed, in most cases the wall thickness is chosen higher. Also may longitudinal stiffeners assumed to be supporting (provided they are properly installed over the whole length), they are not taken into account, because the stiffeners must be dimensioned first. The total effective area is assumed to be the whole cross sectional area of wall plates of the column.

It must be noted that the wall thicknesses obtained in the proofs are not rounded to standard steel plate thicknesses, because it handles a comparison.

The limit state method of EN 13001 requires the smallest wall thickness and the fewest stiffeners, where NEN 2018/2019 and the FEM require the highest wall thickness. The DNV requires not a very large wall thickness, but requires more stiffeners.

Conclusions

Critical conditions
In none of the cases fatigue is the critical condition. In all cases except the DNV buckling is a critical condition. The reason why buckling is not a critical condition in the DNV is that the DNV has a minimum wall thickness depending on the type of structure. In table 10.1 the values for the minimum wall thickness are stated. The proofs are done as follows: First the minimum wall thickness according to the yield stress is obtained. Then the other proofs are carried out one by one. If the wall thickness was not big enough, it was increased until it was big enough. In most of the cases in the proof of buckling the wall thickness had to be increased.
The NEN and the FEM are almost the same. The minimum wall thicknesses are the same for almost all cases but the methods differ a little bit. The number of element groups in the fatigue calculation differs and in load combination 1 the slant rope pulling is not taken into account in the FEM. Also the safety factor for plate buckling differs: the FEM uses for all cases 1,7 and the NEN distincts part fields and the total field, in which the part field has a lower safety factor of 1,5. The proof of plate buckling oft the NEN should be done according to DIN 4114, but this standard has been replaced by DIN 18800. DIN 18800 uses also its own safety factors, which are taken into account. The FEM has its own proof of buckling which is lots easier. This is because the FEM is developed by crane manufacturers who want such things to be easy.

Wall thickness according to plate buckling
In the proof of plate buckling every wall thickness can theoretically be enough, but to reduce the number of needed stiffeners, the wall thickness is increased in most of the cases. First was checked how many stiffeners were needed, when the number of stiffeners could be lowered one by adding a little extra wall thickness, it was done. Most of the cases have 4 stiffeners in the wide part and one or two in the side part. Only the DNV has 5 stiffeners in the wide part and the Serviceability limit state of BS 5400 requires 3 stiffeners.
The number of stiffeners in the wide part lies between 3 and 5. In the side part there are 1 or 2 stiffeners.

In table 10.1 the values are given for the minimum wall thicknesses and the needed number of stiffeners. In table 10.2 the percentages are given of the wall thicknesses compared to the maximum wall thickness. The maximum wall thickness is 7,0 mm, in the EN 13001 all. Stress method and BS 5400, Ultimate limit state.

EN13001, limit state method requires the smallest values of the wall thickness and BS 5400 requires the smallest number of stiffeners, it also requires a small wall thickness.

Reference table, absolute values of wall thickness	EN 13001, lim state	EN 13001, all. Stress.	NEN 2018/2019	FEM	BS 5400, ULS	BS 5400, SLS	Lloyds	DNV
According to yield stress	0,0042	0,0050	0,0052	0,0052	0,0039	0,0029	0,0045	0,0069
According to buckling	0,0060	0,0070	0,0067	0,0067	0,0059	0,0045	0,0055	0,0069
According to fatigue	0,0060	0,0070	0,0067	0,0067	0,0059	0,0045	0,0055	0,0069
According to plate buckling	0,0062	0,0070	0,0069	0,0067	0,0070	0,0065	0,0065	0,0069
Number of stiffeners wide part	4	4	4	4	4	3	4	5
Number of stiffeners side part	1	1	1	2	2	1	2	2

Table 10.1 Minimum wall thicknesses and required number of stiffeners

Reference table, percentages of maximum wall thickness	EN 13001, lim state	EN 13001, all. Stress.	NEN 2018/2019	FEM	BS 5400, ULS	BS 5400, SLS	Lloyds	DNV
According to yield stress	60	71	74	74	56	41	64	99
According to buckling	86	**100**	96	96	84	64	79	99
According to fatigue	86	**100**	96	96	84	64	79	99
According to plate buckling	89	**100**	99	96	**100**	93	93	99

Table 10.2 Percentages of maximum wall thickness