DISCUSSION

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The lateral torsional buckling strength of hot-rolled 3CR12 beams

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COMMENT 1

I have a few comments to make about the paper and would like to have the authors' response.

I see that the authors used an equivalent effective length factor of 0,7. The theoretical effective length factor for a fully fixed case is 0,5 and for a pinned end 1,0. Their test setup could have given an effective length of anywhere between 0,5 and 1,0. Why did they decide on a factor of 0,7 when this value did not give them a particularly good fit? It would have been possible to back-calculate the actual value if they had taken the results of the elastic buckling of the 300WA steel and compared them to the theoretical buckling strength.

If one is going to compare test values with theoretical code values, one must use the material properties as measured, that is, modulus of elasticity and yield strength. One cannot compare small sample test values with theoretical values based on characteristic values of the population.

For instance, if one is going to compare the IPE_{AA} section results, the average measured E for the 300WA steel = 210,7 GPa and the yield stress = 371,3 MPa.

For a slenderness L/r_y = 305, the length is 3 690 mm. This leads to a theoretical Mcr = 5,163 kN.m if the effective length factor is taken to be 0,7. Could the authors please explain how they got to a value of of 4,4 kN.m for M_{cr} (see figure 5 or table 2) unless they applied a partial material factor. Even the capacity reduction factor of 0,9 does not give a value of 4,4 kN.m. The equation for M_{cr} in the code, SANS10162-1 does not contain any partial material factors, so it would be incorrect to call their calculated values 'critical moment resistance'.

If one eliminates the capacity reduction factor from both the test values and the theoretical buckling values, the effective length factor may be back-calculated from the test value M_{cr} = 6,55 kN.m. The effective length factor will be equal to 0,569. For example, one could use an effective length factor of 0,6 and compare the other test results.

For a slenderness of L/r_y = 203, the theoretical critical moment, M_{cr} = 10,154 kN.m. For the section M_p = 11,844 kN.m. $M_{cr} > 0,67 \times M_p$, therefore the resistance moment is given by the transitional curve and the theoretical M_r, without taking any material factors into account = 9,172 kN.m. Compare this to a test value of 9,222 kN.m.

For slenderness $L/r_y \leq 102$, M_p governs and the theoretical value for M_r, without partial material factors, = 11,844 kN.m, test value = 10,556 kN.m. At this stage the authors should have tried to explain the discrepancy between the theoretical values and the test values.

I find the paper confusing as the authors mention maximum moments and critical moments, but appear to have applied partial material or capacity reduction factors to all of the theoretical values, but to only some of the test results. I get the impression that they were not consistent in their application of partial material factors. If one looks at the test results for the IPE_{AA} 100 x 55 it appears that the test values for the 300WA steel have had the reduction factor applied, whereas there appears to be no partial material factor applied to the 3CR12 test values. My reason for making that statement is that the critical moments, M_{cr} given in table 2, of the 3CR12 specimens are higher than that of the 300WA steel, but the measured modulus of elasticity of the 3CR12 is lower than that of the 300WA steel. The plastic moment of resistance, M_p, of the 3CR12 should be no more than 2 % higher than that of the 300WA as the average yield stress, according to table 1, is only 2 % higher for the 3CR12. Perhaps the section dimensions were not the same size. If this was the case, the authors should have picked it up and pointed it out in the paper.

Noting the above inconsistencies and errors leads to a lack of confidence in the rest of the paper.

W M G Burdzik

RESPONSE 1

The authors thank Professor Burdzik for his interest in the paper and his comments. The comments will be addressed in the same sequence as they were made.

The authors' intention was to use the SANS 10162 code as prescribed and not to obtain theoretical effective length factors by using experimental data. A practising engineer generally does not have experimental data at his or her disposal prior to his or her design, but is guided by the proposed boundary conditions. The code prescribes three effective length factors for normal loading. The use of 0,7 was deemed most appropriate in accordance with the experimental set-up, while rendering the highest possible predicted values for comparison.

As mentioned previously, SANS 10162 prescribes the use of 200 GPa for the modulus of elasticity and 300 MPa for yield strength. No responsible practising engineer will use higher values in his design unless he can guarantee these properties. The code is not theory to be used for comparative purposes. It specifies minimum 'safe' resistance based on various assumptions and restrictions, including material properties. The code is partially based on theory, experimental work, some statistical manipulation and common sense. The material properties of the 300WA and 3CR12 sections were determined for two reasons: first, to ascertain compatibility of the materials to the minimum code requirements: and second for direct comparative purposes to one another.

Figure 9 compares the experimental test results (300WA IPE_{AA} 100×55) with the normalised code predicted values. The normalised code values are an attempt to compare the samples under investigation with a 'generalised' code. Basically an attempt to compare apples with apples, that is to remove the difference in real material properties and sectional sizes. Therefore the actual material properties and sectional sizes as tested are used and the capacity reduction factor is set to unity. In this context the values are correctly calculated, ie M_{cr} = 5.163 kN.m (L/r_y = 305). When applying the code and therefore using E = 200 GPa and σ_y = 300 MPa and a capacity reduction factor of 0.9 one then obtains M_{cr} = 4,4 kN.m as used in figure 5. There is no mistake or inconsistency here.

The experimental results for buckling tests conducted on 300WA and 3CR12 IPE_{AA} 100×55 sections are presented in table 2. The SANS 10162 code predicted values are also presented. The 3CR12 sections were marginally bigger, as clearly indicated by the difference in the non-dimensional slenderness ratio, therefore the plastic limit when using the actual sectional properties will also be different.

An explanation for the marked difference in strength for the short lengths was beyond the scope of the study and of little practical interest, but is probably because of the heightened strain hardening characteristics that is a well-known characteristic of stainless steels in general. The austenitic grades are notorius for this.

The main aim of the paper was first to present real world experimental data of 3CR12 hot rolled sections and to compare it directly to 300WA. Second, the experimental data was compared to the appropriate SANS code when using the minimum specified values and restrictions as the code prescribes, as would be applied in a typical design. In all cases the code predicted values were conservative, as one would expect. This conservatism is largely because of the higher than minimum material and sectional properties illustrated by the sections tested and the applied capacity reduction factor. Lastly, an attempt was made to compare the experimental results with the values that the code would predict if the real material and sectional properties were used along with a reduction factor of unity. In this, we believe we succeeded admirably.

J J Klopper and R F Laubscher

COMMENT 2

1 I would like to congratulate the authors on a very interesting and informative paper, on a product well known for its corrosion-resisting properties and far less on for its structural properties.
2 I have the following queries, the answers to which would enhance my knowledge of 3 CR 12.
   2.1 An explanation on the various symbols used such as σ_y, σ_p, COV, etc. A glossary should be provided of all the symbols used in the paper should be provided.
   2.2 A buckling resistance moment of $M_{b.Rd}$ (1) is mentioned in the text on page 10. I however do not find it stated in the tables and in the figures. Where has it been used?
3. Grade 300 for structural steel is being replaced by Grade 350 with almost immediate effect and then Grade 300 will no longer be available, except in certain special circumstances.

Any further experimental work should be done on Grade 350 steel and not on grade 300 steel.

I would appreciate a reply from the authors to my comments in due course.

R L Hicks

RESPONSE 2

The authors thank Mr Hicks for his interest in the paper and his comments. The comments will be addressed in the same sequence as they were made.

The following is a list of the symbols and their meaning with respect to the article. This list should have been added in the original article by the authors for clarity.

E_0 – Initial modulus of elasticity
σ_y – Yield strength (determined by 0,2 % strain offset for gradual yielding material)
σ_p – Proportional limit (determined by 0,01 % strain offset for gradual yielding material)
COV – Coefficient of variance (indication of scatter for statistical data)
L/r_y – Non dimensional slenderness ratio about the weakest axis
M_p – Plastic buckling moment
M_{cr} – Critical buckling moment

The buckling moment resistance ($M_{b.Rd}$) defined as outlined in equation 1 is the method used by Eurocode 3 to estimate the buckling moment of a beam subjected to bending. These values were determined and are presented in tables 2, 3, and 4, as well as in figures 5, 6, and 7 under the heading Eurocode 3. The values are included for comparative purposes with the South African code, SANS-10162-1.

When the work was commissioned and the experimental work conducted, 300WA was the only commercially available structural steel. 350WA only appeared after the experimental work had been concluded and the review process initiated. This is unfortunate, but currently a project to investigate the structural behaviour of 350WA in more detail has been initiated. Moreover, at about the same time as the paper being commented on appeared, Mittal Steel South Africa decided to finally end all production of hot-rolled 3CR12 sections, which is a sad day for technological innovation in South Africa.

J J Klopper and R F Laubscher