SHORT TERM SCIENTIFIC MISSION – COST ACTION TU0904

BENCHMARK STUDIES FOR STEEL BEAMS, STEEL FRAMES AND COMPOSITE STEEL BEAMS – SCIENTIFIC REPORT

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1. INTRODUCTION

The aim of short term scientific mission was calculation of benchmark studies of simply supported steel and comparison of results between different numerical software. Analyses were performed using two software's. First one is Vulcan developed at the University of Sheffield in the Department of Civil and Structural Engineering. Vulcan is software which allows determining the response of the structure during the fire. It focuses primarily on the response of steel and composite steel-concrete structure in fire. And from the University of Ljubljana software named *Fire* and *CompositeFire* was used to determine the response of structure during the fire. Software allows us to determine the response of steel and composite concrete-steel elements during the fire. Focus of benchmark studies was to prepare simple cases that are not complex, yet they enable numerical verification of the numerical models or different software's for calculation of mechanical response of the steel structures exposed to fire.

2. DESCRIPTION OF THE WORK

Fire analysis is divided in two independent phase. To keep the cases as simple as possible the heating regime was usually linear, or in some cases equal to the ISO834 standard fire curve. In the second step of the fire analysis, the stress and strain fields due to the combined effects of mechanical and thermal loads are obtained. In a series of benchmark cases, various scenarios were considered, in which the load q, the heating regime, the material model and the boundary conditions were changed. A list of cases is given in tabular form in Table 1.

2.1 Thermal analysis

The focus of this study is on mechanical behaviour, and therefore thermal analysis is in most cases omitted. When there is no thermal analysis the temperature in steel cross-section is considered as uniform and equal to the time-temperature curve of the heating regime; in the examples defined in Tables X.1 and X.2, the thermal analysis is denoted as 'None'. Otherwise the simplified method given in EN 1993-1-2 (2005) is used to calculate the increase of temperature in an unprotected steel member. During a time interval Δt a uniform steel temperature is calculated using the incremental equation

3.1 Mechanical analysis

All cases have been modelled with the software 'POZAR'. This program uses a strain based finite element formulation to determine the mechanical response of the planar frame subjected to time-varying mechanical and temperature loadings. The formulation is based on the kinematically exact planar beam theory of Reissner (1972). The remaining unknown functions, (the displacements, rotations and internal forces and moments) appear in the functional only through their boundary values. The finite element formulation yields a system of discrete generalised equilibrium equations of the structure, which are solved by the Newton incremental iterative method.
In the model an iterative method is used, and the whole time domain is divided into time increments $\Delta t = t^i - t^{i-1}$. Based on the given stress and strain state at the time ti-1 and temperature T at ti, we can determine the geometrical strains D of any point of the steel beam at time t. Considering the principle of additionality of strains and the material models of steel at elevated temperatures, the strain increment, ΔD^i, consists of the sum of the individual strain increments due to temperature, stress, and creep strain. The temperature strain increment is calculated from the EC 3 formula. The creep strains are explicitly considered only when a bilinear material model is used, when they are calculated with the help of the Williams-Leirs (1983) model. In the presented analyses the stress-strain relationship of steel at elevated temperatures, and its thermal expansion strain, are taken from EN 1993-1-2 (2005) in most cases. The reduction factors for the mechanical properties of steel are also in accordance with Eurocode 3. In some cases a bilinear material model (Srpčič, 1991) was used and reduction factors according to the French standard (CTICM, 1976) were used.

3. EXAMPLE: SIMPLY SUPPORTED STEEL BEAM

The beam, having an UB 406×178×67 cross-section and a length of 8.00 m, are subjected to a constant uniform load q and then heated uniformly along the entire length (Fig. 1).

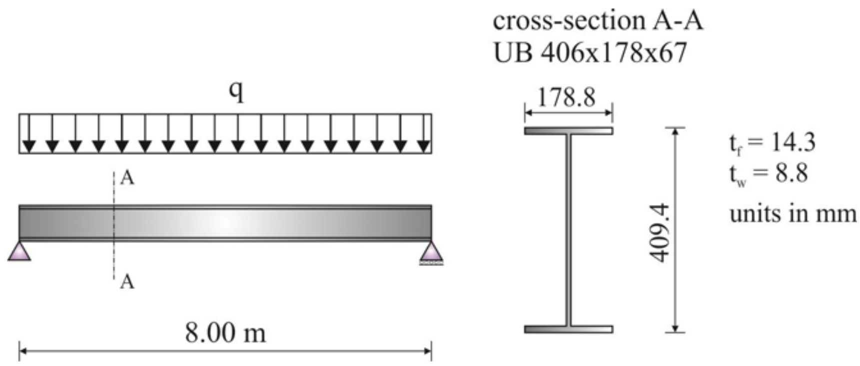

Figure 1: Simply supported steel beam

Table presents the full lists the performed analyses.

Table 1: List of performed analyses.

Name	**Material model**	**Load q [N/mm]**	**Heating regime**	**Thermal analysis**	**Creep**	**Boundary conditions**
SS_B1	EC 3	20 and 40	linear 30C/min	none	NO	pin - roller
SS_B2	EC 3	20 and 40	linear 30C/min	none	NO	pin - pin
SS_B3	EC 3	20 and 40	ISO834	Simplified, EC3	NO	pin - roller
SS_B4	EC 3	20 and 40	ISO834	Simplified, EC3	NO	fix - fix
SS_B5	Bilinear	20 and 40	ISO834	Simplified, EC3	YES	pin - roler
SS_B6	Bilinear	20 and 40	ISO834	Simplified, EC3	YES	fix-fix

3.1 Results

Next we present just some of the results form analyses are presented. On Fig 2 – Fig. 6 mid-span displacement for the cases in SS_BB1 to SS_BB6 are presented.

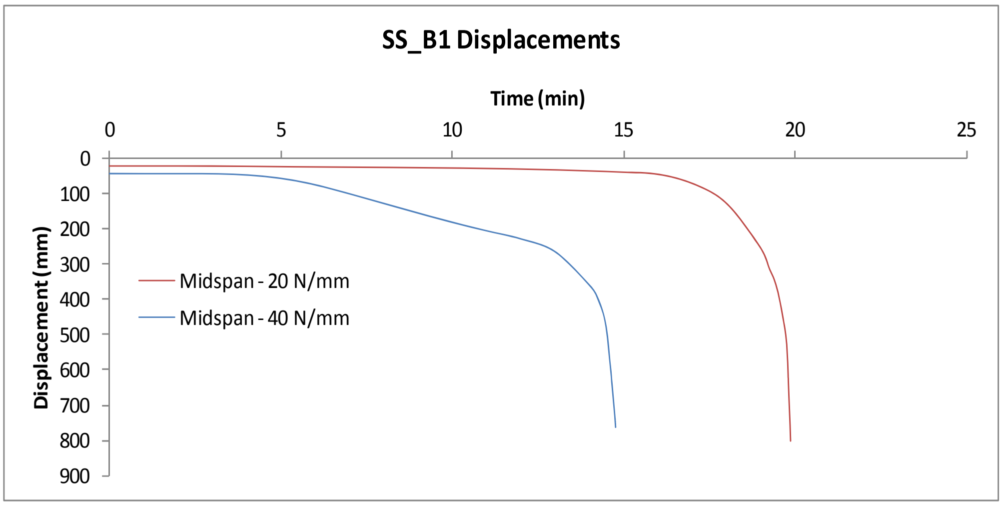

Figure2: Midspan displacement for case SS_B1

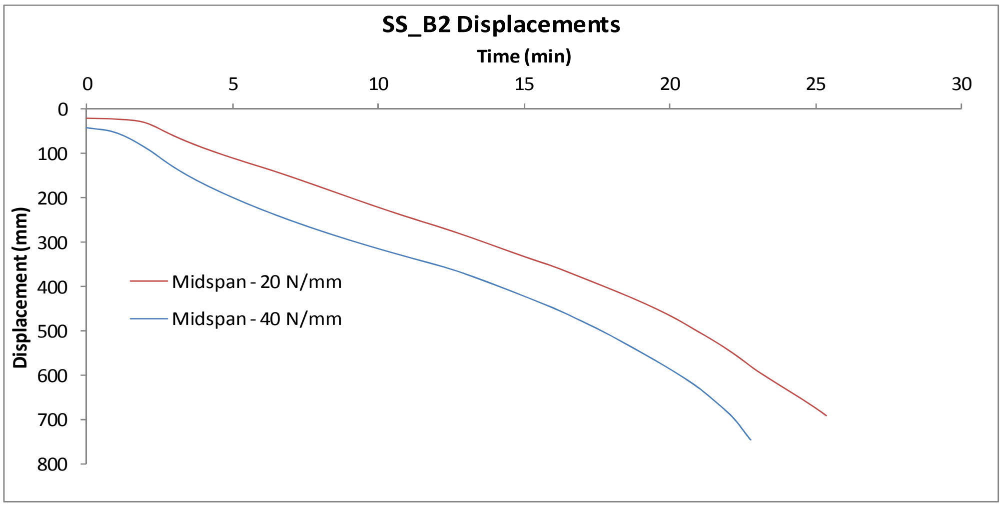

Figure3: Midspan displacement for case SS_B2

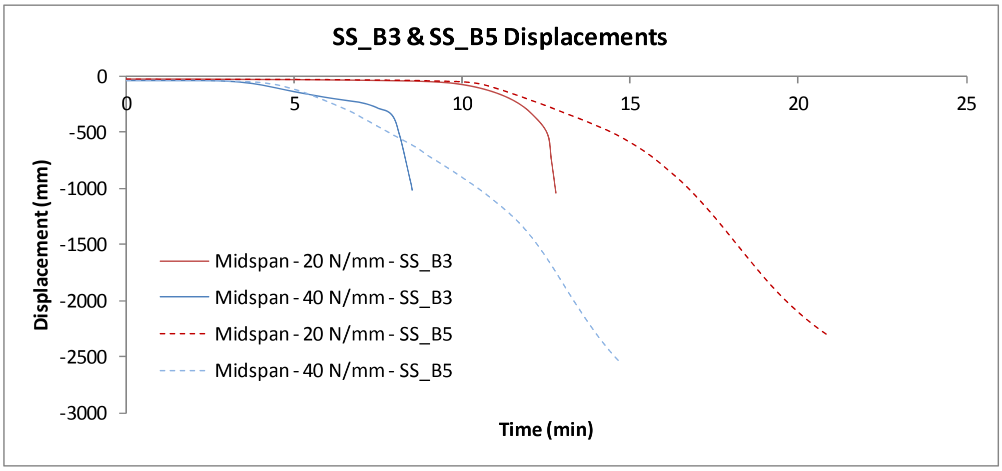

Figure 4: Midspan displacement for case SS_B3 and SS_B5

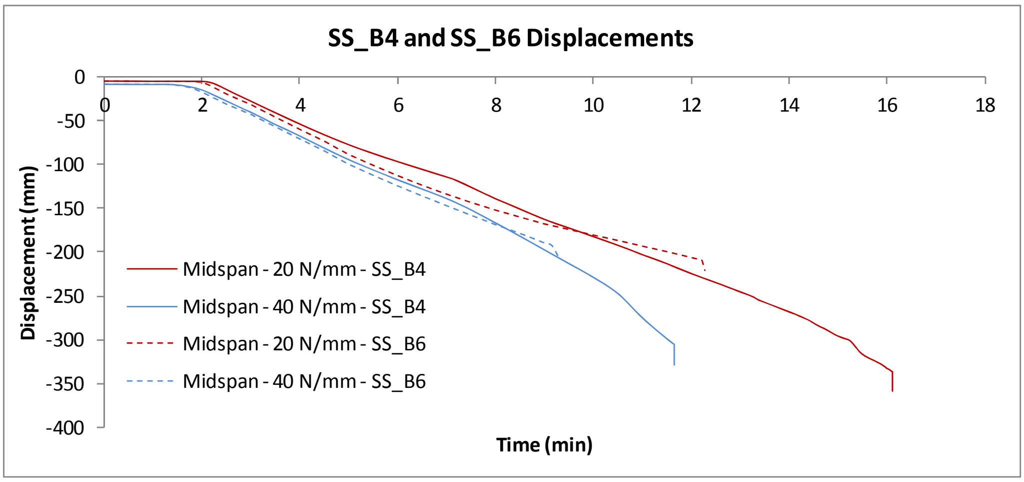

Figure 5: Midspan displacement for case SS_B4 and SS_B6

4. CONCLUSIONS

In the short term scientific mission we provided benchmark studies for steel beams, steel frame and composite steel-concrete beam. The results are presented for various load levels, boundary conditions. Two material models were considered. In material model according to EN 1993-1-2 creep of steel at elevated temperature is considered explicitly while in bilinear material model creep is considered explicitly.