STSM Scientific Report

COST Action TU0904

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Period of STSM: 10/03/2012 – 20/03/2012

Purpose of the visit

The main purpose of the reported COST Short Term Scientific Mission (STMS) was to develop advanced Finite Element models of the representative structural systems for the purpose of structural analysis in case of fire. The idea standing behind this initiative was to exchange the research experience accumulated at FEDRA Buro Happold and at Warsaw University of Technology (WUT). The steel frame of ME Hotel Aldwych in London was chosen for the modeling. The structure was subjected to different fire scenarios based on fire assessment done at FEDRA Buro Happold. Both beam and shell elements were used ~~I~~in the numerical model to simulate more precisely behavior of the structure at elevated temperatures. Special attention in numerical modeling ~~is~~ was paid to the detailed analysis of elements which buckle during fire and may have significant effect on the global behavior of the structure.

The tool for these analyses was a FE model developed using commercial software LS-DYNA®. The model development was done using ~~public domain~~ graphical pre-post-processor LS-PREPOST. All calculations were run remotely on the computational cluster located at WUT.

Description of the work carried out during STSM

The first part of the work carried out during this STSM was a numerical analysis of an example problem using beam elements only to compare with the results obtained using VULCAN software used at FEDRA Buro Happold.~~, while i~~In the second part of the work all the structural elements in the vicinity of the fire were modeled using shell elements, which allowed for more detailed analysis of potential local buckling. The ~~M~~model of the analyzed structure is presented in Fig. 1. Lateral stability of the frame in the actual structure is provided by 2 concrete cores which are located outside the frame and are connected to the structural elements through the concrete slabs. To avoid modeling of whole concrete parts, ~~cores~~ the effective global stiffness of the building was calculated and replaced with a single core inside the steel frame with proper stiffness. In the numerical model ~~S~~steel elements are connected by rigid connections to the middle core. Concrete slabs also provide a constraint on the thermal expansion of the frame, so ~~in~~ the model included 1m of the slab on the perimeter of the frame, ~~which is~~as presented in Fig. 1.

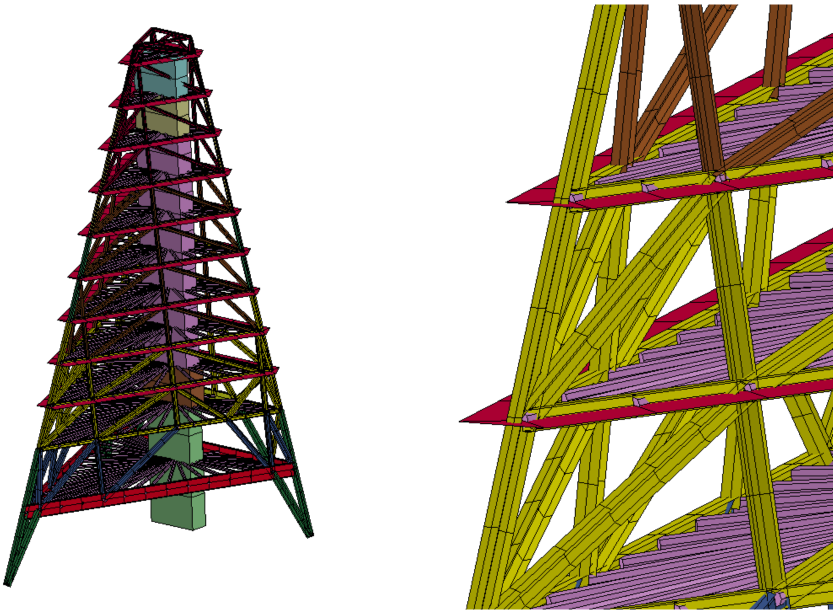


Fig. 1. LS-DYNA model of a steel frame in ME Hotel Aldwych.

The temperature distribution was evaluated using a localized fire heat transfer model which represents the fire as a layered cylinder of different temperatures. For this case the temperature cylinder is composed of three layers based on the geometric components of a localized fire: the continuous flame, the intermittent flame and the thermal plume. Material properties were calculated according to Eurocode, evaluating all the material properties for 8 ~~values~~ levels of temperature~~s~~, while the properties between the given points are linearly interpolated. The ~~F~~fire assessment of the analyzed structure was based on the global behavior of the frame. Histories of vertical displacements of the top nodes presented in Fig. 2 (nose, rear north and rear south) were registered and assumed that the structure is safe in case of assumed fire if all the displacements are increasing during fire.

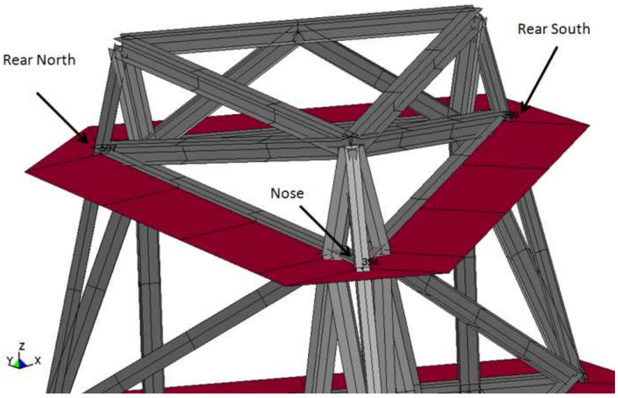


Fig. 2. Location of nodes for vertical deflection measurement.

To analyze in detail~~s~~ the area where the steel temperatures are the highest and buckling occurs, a combined model was created in which all the elements with temperature higher than 300 Celsius degrees were modeled using shell elements. The close ~~up~~ view of the area modeled using shell elements is presented in Fig. 3. All the joints were modeled as rigid by creating ~~a~~ nodal rigid bodies.

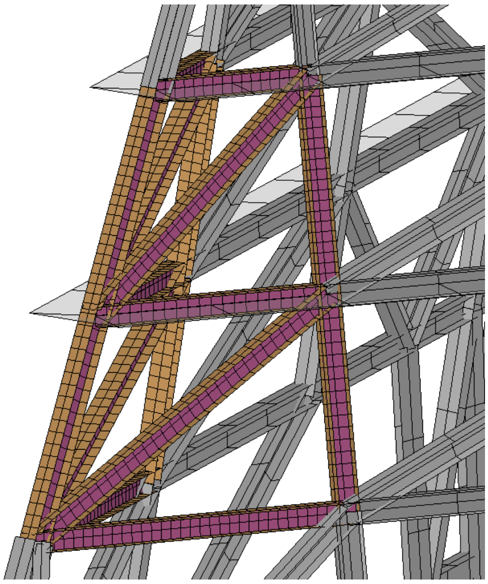
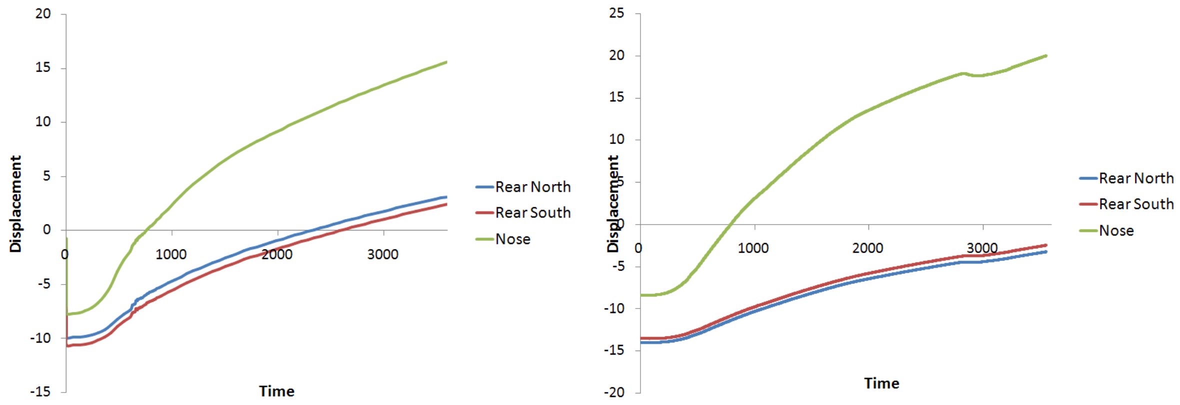


Fig. 3. Combined beam and shell element model of the frame.

Description of the main results ~~obtained~~

The most important result obtained ~~during~~ in the fire assessment of such ~~a~~ structure is vertical displacement of the top of the frame however,~~, but~~ the temperature distribution, stress state and plastic strains may also be useful to analyze more closely the behavior of the structure. ~~In~~ Fig. 4 ~~presented~~ presents comparison of results obtained ~~in~~ by VULCAN and LS-DYNA model in which only beam elements were used.

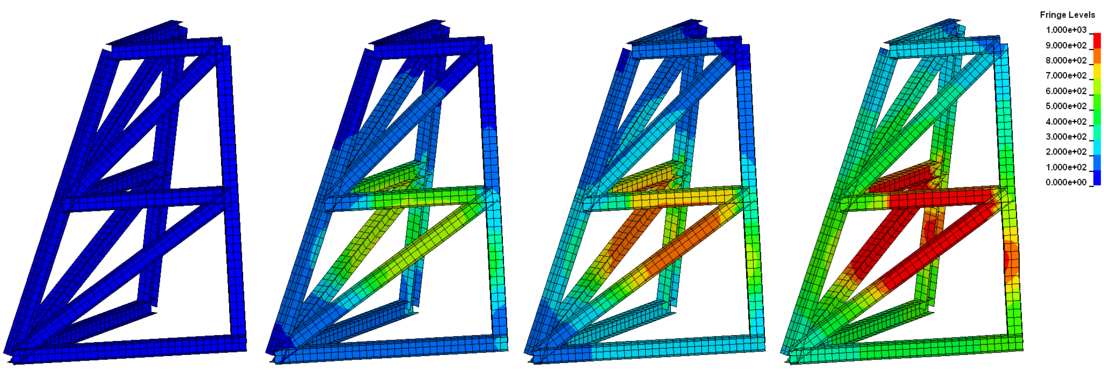


a) VULCAN b) LS-DYNA

Fig. 4. Comparison of results obtain in VULCAN and LS-DYNA using beam elements only.

From the comparison of the results for the model made totally of beam elements it can be noticed that the there is a small decrease of vertical displacements in LS-DYNA model due to buckling of elements, though after the buckling and stress redistribution all the displacements are increasing. Differences in the values of vertical displacements might be due to the different way of application of thermal loading, because in VULCAN the thermal loading is applied to the whole beam element, while in LS-DYNA the thermal loading is applied to the nodes and the temperature along the beam is variable. ~~but~~ However, the overall behavior is similar and ~~in~~ based on both models it can be assumed that the structure is safe in case of fire.

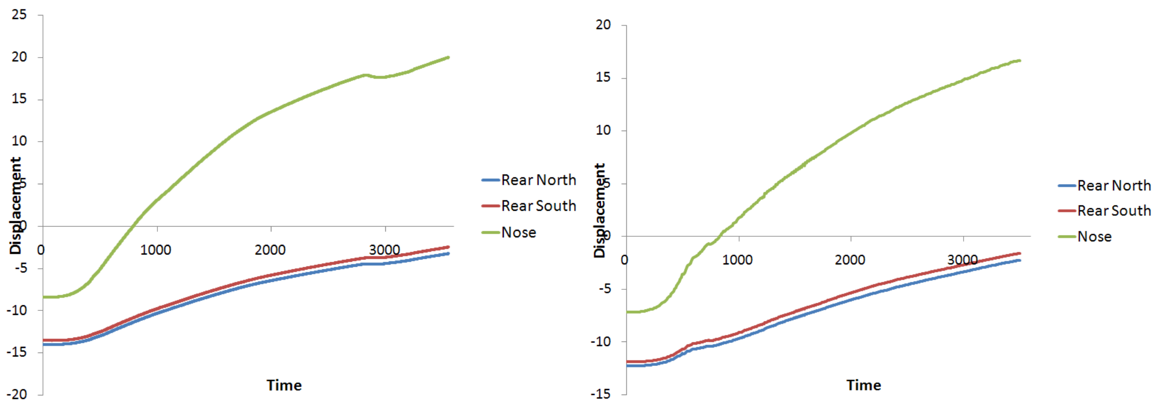
To analyze in detail~~s~~ the effect of buckling ~~at the behavior~~ of the structure, ~~used~~ shell elements were used for the part of the frame which is close to the fire. ~~applying t~~The temperature history based on fire heat transfer model was applied for each node of the structure. ~~In~~ Fig. 5 ~~presented~~ presents temperature distribution in the frame structure for different time of fire.



t=0s *t=800s* *t=1200s* *t=3000s*

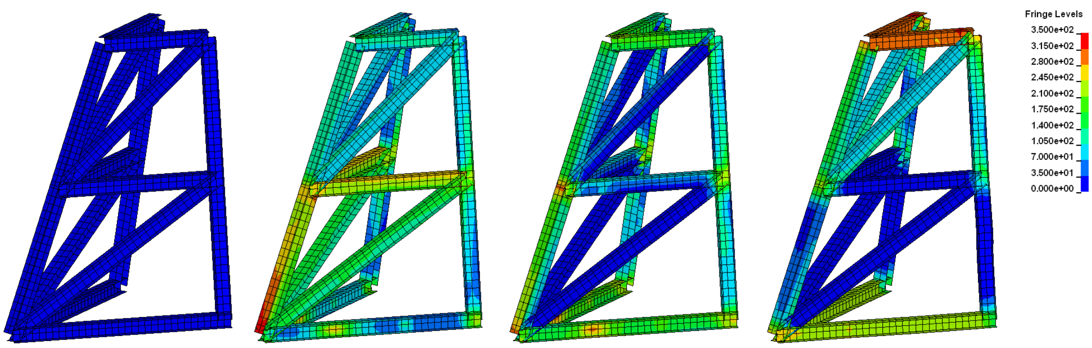
Fig. 5. Temperature distribution in the part of frame modeled using shell elements.

~~In~~ Fig. 7 ~~presented~~ presents comparison of the top node~~s~~ vertical displacements for two models in LS-DYNA. It can be noticed that in the combined model, the buckling of the elements occurs sooner and has smaller effect on the global behavior of the structure than in the case of model built of beam elements only. Fig. 8 presents contours of effective stress in the elements for different time of fire, showing which elements buckled and for which the stresses are decreased. The exact ~~location of plastic strains are~~location of plastic strains is presented in Fig. 9.



a) Beam elements b) Combined beams and shells

Fig. 7. Comparison of results obtain in LS-DYNA, using beam elements only and combined beam and shell elements.



t=0s *t=800s* *t=1200s* *t=3000s*

Fig. 8. Effective stress distribution in the part of frame modeled with shell elements.

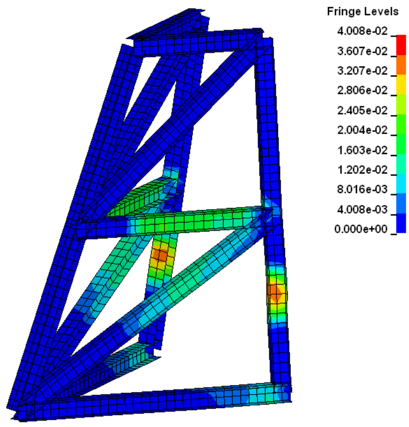


Fig. 9. Development of plastic strains in the elements modeled using shell elements.

Comparison of the simple and more advanced models suggest that even though there are some differences in the local behavior of the structure its overall behavior is similar and in both cases it can be assumed that the structure is safe in case of assumed fire.

Future collaboration with the host institution

Both institutes are interested in future collaboration concerning further analyses of structural systems, exchange of methods and experiences connected with the fire modeling.

Foreseen publications / articles resulting or to result from the STSM

Based on the results obtained during the STSM there is a planned paper for a conference.

Confirmation by the host institution of the successful execution of the mission

See annex 1.