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STABFI – RFCS project

KULDEEP VIRDI City, University of London

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RFCS Project - STABFI

Steel cladding systems for stabilization of steel buildings in fire

OUTLINE

- Participants, Budget and Time Frame
- Context – ECCS recommendations for stabilisation using sandwich panels at ambient temperatures
- Work Packages and Deliverables
- Results of Work Package 1 (Responsible: City)
- Scope of other Work Packages
- Some observations on applications for EU funding
- Conclusion

STABFI – PARTICIPANTS, BUDGET AND TIME FRAME

Slide 3/54

PARTICIPANTS IN STABFI

Tampere University of Technology, Finland (Coordinator)
Czech Technical University in Prague
City, University of London
Budapest University of Technology and Economics
Brandenburg University of Technology, Cottbus
Häme University of Applied Sciences, Hämmenlinna

Ruukki Construction Oy, Finland
Kingspan Research and Developments, Czech Republic
SFS Intec Oy, Finland

BUDGET

Total Budget of the project	€1.438M
City Share	€236K

RFCS rules allow reimbursement of only 60% of the project costs. The remaining 40% have to be supported by the 'beneficiary'.

The budget includes 'Indirect costs' at the rate of 35% of personnel salaries. Any travel costs are to be paid out of Indirect costs.

TIME FRAME

Start Date	**1 July 2017**
End Date	**30 June 2020**

REPORTING

First Report	**31 December 2017**
Mid Term Report	**60 days after 31 December 2018** **Includes Financial Statement**
Final Report	**60 days after 30 June 2020** **Includes Financial Statement**

A significant number of Milestones and Deliverables

CONTEXT

Slide 5/54

STABFI – CONTEXT

Design recommendations exist for member and frame stabilization by cladding of single storey structures in ambient temperatures to achieve considerable savings.

Knowledge and design rules for fire conditions are not available. Without relevant knowledge, the stabilizing effect of cladding may be left unutilized under fire conditions

ECCS RECOMMENDATIONS
AMBIENT TEMPERATURE DESIGN

Slide 14/54

ECCS RECOMMENDATIONS

European Recommendations on the Stabilization of Steel Structures by Sandwich Panels, were published in 2013.

These were developed after a major research project on the topic, EASIE, (Ensuring Advancement in Sandwich Construction through Innovation and Exploitation), 2008-2011.

This was an FP7 funded project.

ECCS RECOMMENDATIONS

Main design aspects covered by ECCS Recommendations include:

1. **The torsional restraint given by sandwich panels to members of the structural frame.**
2. **Lateral Restraint: In-Plane Shear Resistance**

TORSIONAL RESTRAINT

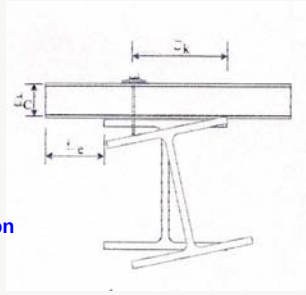
Slide 5/54

TORSIONAL RESTRAINT

The torsional restraint is governed by the stiffness of the connection of the sandwich panel to the supporting structure. The spring stiffness is a combination of the bending stiffness of the attached panel, the stiffness of the connection, and the distortional stiffness of the beam to be stabilized.

TORSIONAL RESTRAINT

Forces in sheet/purlin fasteners and reaction forces arising shall be considered.
Beyond that, no additional forces from the stabilization occur.



TORSIONAL RESTRAINT

An additional check needs to be made, limiting the rotation and therefore the danger of leakage under serviceability load conditions.

For uplift loading, no torsional restraint is available. The in-plane shear resistance of the panels can be utilized for stabilizing both for downward and uplift loading.

TORSIONAL RESTRAINT

ECCS Recommendations give formulae for calculating the stiffness coefficients required using the geometrical properties of connected elements and fasteners and their elastic properties.

EVALUATION BY EXPERIMENTS

ECCS Recommendations also suggest a test arrangement for determining the stiffness coefficients involved. Specifically, they advise against using the method in Eurocode 3, Part 1.3.

The same setup has been adopted when determining the stiffness coefficients under elevated temperatures under relevant Work Packages.

IN-PLANE RESTRAINT

Slide 5/54

IN-PLANE RESTRAINT

Sandwich panels have a high stiffness and strength when loaded in the plane of the panel. This can be used to stabilize the supporting structure of the panels (beams, purlins, columns).

The deformation of sandwich panels themselves caused by in-plane shear load may normally be neglected.

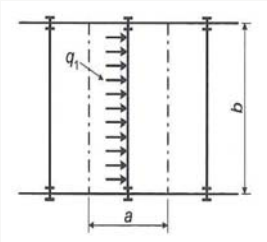
IN-PLANE RESTRAINT

The flexibility of the fixings usually dominates the shear flexibility.

The fixings must be designed for the in-plane shear load.

IN-PLANE RESTRAINT

With the stiffness of the fastening known (from calculations or experiments), the shear force of a fastening can be determined. Formulae are given in ECCS Recommendations.



STABFI – PROJECT OBJECTIVES

Slide 5/54

STABFI – PROJECT OBJECTIVES

To derive validated design rules to include

- **Natural fires in single storey industrial or commercial buildings;**
- **Translational and rotational stiffness and resistance of typical joints between cladding and steel frames;**
- **Temperatures of connectors and steel members near cladding structures.**

STABFI – PROJECT SCOPE

Single-storey industrial buildings stabilized by sandwich wall panels and trapezoidal sheeting or sandwich panel roof elements.

Supporting members: I-profiles and hollow sections.

Connectors: typical screws and nails.

Natural fire for temperature distributions.

STABFI – WORK PACKAGES

Slide 10/54

STABFI – WORK PACKAGES

The project is divided into 9 Work Packages

WP1 - Design Natural Fires

WP2 - Panel and joint tests in fire

WP3 - Full-scale furnace tests

WP4 - Tests in normal conditions simulating fire

WP5 - FEM model development and validation

WP6 - Design of an entire building stabilised using sandwich panels

WP7 - Design rules, guides and software

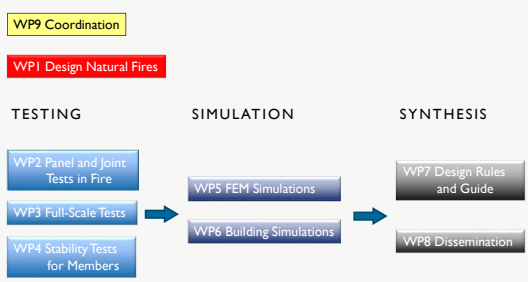
WP8 - Dissemination

WP9 - Coordination

STABFI – PROJECT TIME SCHEDULE

	Work package title	WP Leader	1st year				2nd year				3rd year			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
✓ WP 1	Design natural fires	CITY												
✓ WP 2	Panel and joint tests	CVUT												
✓ WP 3	Full-scale tests	TUT												
WP 4	Tests in normal conditions simulating fire	BME												
WP 5	FEM model development and validation	BTU												
WP 6	Stabilization of entire building by sandwich panels	TUT												
WP 7	Design rules, guides and software	CITY												

STABFI – WORK FLOW STRATEGY



CITY RESPONSIBILITIES

City is the lead institution for two Work Packages

WP1 – Design Natural Fires

WP7 - Design rules, guides and software

No experiments at City. Only desk and computer work.

Results of WP1 will be described in some detail in this presentation.

CITY RESOURCES

Principal Investigator	Approx. 4 person-months
Co-Investigator	Approx. 5 person-months
RA	12 person-months

RA will commence in about 2 months.

PROJECT DELIVERABLES

A list of 15 substantial deliverables

City's Responsibiliy:

City	Month 9	Design Natural Fires
CVUT+City	Month 9	FDS and CFAST calculations
City	Month 36	Design rules, guides and software

STABFI – WORK PACKAGE 1

Slide 14/54

WP1 - TASKS

1. Review national fire regulations for single storey industrial and commercial buildings, use of cladding in normal and fire situation.
2. Perform FDS simulations varying input data.
3. Perform CFAST simulation using same input data as for CFAST.
4. Guidelines for gas temperatures.
5. Recommendations to use FDS and CFAST for the type of buildings being considered.

WP1 - DELIVERED

D1.1 - Evaluation of National Rules

The relevant regulations of England, Finland, Hungary, Czech Republic and Germany were explored.

Building Regulations in all countries reviewed converge on specifying the fire durations.

WP1 - DELIVERED

In the regulations, various criteria used include:

- **Height of building**
- **Nature of materials of the structure and cladding**
- **Intended use of the building in terms of stored materials (classifying risk)**

Because of slightly different criteria for determining the severity of fire, the required fire durations in the partner countries may be slightly different in borderline cases.

There is nothing in the regulations that prevents the use of cladding as means of stabilising the structural frame.

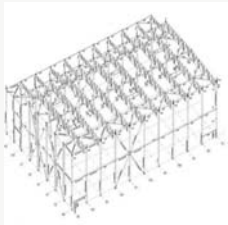
WP1 - DELIVERED

D1.2 - Recommendation for FDS and Ozone simulations

Two different approaches - a rigorous one, but time consuming, based on computation fluid dynamics (NIST-FDS) and an approximate one, and hence rapid to use, based on two-zone model (NIST-CFAST) were evaluated in the project.

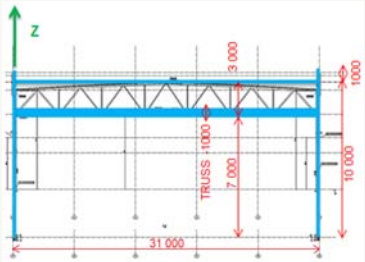
WP1 – BUILDING FOR FIRE MODELLING

Building to be studied was obtained from Ruukki (a real building located in Tampere, Finland).



WP1 – BUILDING FOR FIRE MODELLING

Building Cross-section



WP1 – SOFTWARE EMPLOYED

Two public domain pieces of software, FDS (at Czech Republic) and CFAST (at City), were employed to obtain design temperatures at various locations and with different ventilation parameters.

The two programs were developed at NIST and were employed extensively in the studies on World Trade Center buildings.

WP1 - DELIVERED

Three fire scenarios were considered

- **A car burning in the building (fork-lift device)**
- **3 pallets of cardboard boxes with PET bottles inside**
- **As above but simulated as travelling fire (FDS only)**

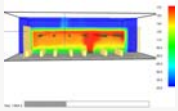
Temperature versus time characteristics for the combustion of the fire load were obtained from experiments done by Ruukki.

(PET = Polyethylene terephthalate)

WP1 – ILLUSTRATIVE COMPARISON

Local fire - car on fire with a small door in the compartment

FDS

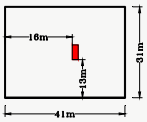


Max temperature 185° C at 23.6min.

CFAST

Upper layer 86.4 ° C

Location of source



WP1 - CONCLUSIONS

CFAST consistently underestimates the maximum localised temperature compared with FDS. This is inevitable, as it is an averaging process for calculating temperatures.

Location of the car (fork-lift) makes only a small difference

Although the required deliverable has been 'delivered', it has been decided to carry out further comparisons to provide more general guidance on the use of CFAST.

STABFI – WORK PACKAGE 2

Slide 22/54

WP2 - PANEL AND JOINT TESTS IN FIRE

Tests in both normal temperatures and elevated temperatures, aimed at obtaining reference values for stiffness and resistance of the joints.

These tests are planned to provide experimental data for the most important variables concerned with structure stabilization and for validation of the design rules to be developed in the project.

WP2 - PANEL AND JOINT TESTS IN FIRE

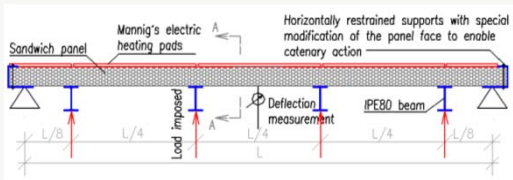
Test results will be used as:

1. **Input data in WP4 (normal conditions simulating fire) and WP6 (Stabilization of entire building using sandwich panels)**
2. **For numerical validation and a subsequent parametric study in WP5 and design guidance developed in WP7.**

Tests will represent typical cases which are commonly used by designers.

WP2 - PANEL AND JOINT TESTS IN FIRE

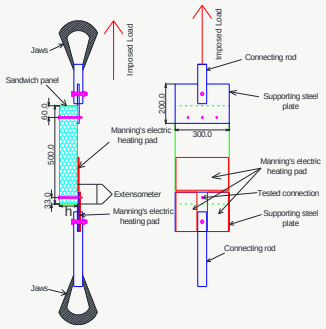
Test Configuration for Bending Stiffness (15 tests):



Test specimen after failure

WP2 - PANEL AND JOINT TESTS IN FIRE

Test Configuration for Translational Stiffness:



STABFI – WORK PACKAGE 3

Slide 26/54

WP3 - FULL-SCALE FURNACE TESTS

Experimental test results are aimed at the validation of numerical models and simulations in WP5 and the design rules in WP7.

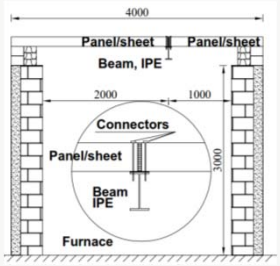
Full scale furnace tests (17) of roofs under different fire exposure conditions are planned, aiming at the determination of the temperature fields in steel sections, trapezoidal sheets, sandwich panels and joints.

WP3 - FULL-SCALE FURNACE TESTS

Also, the stability and load bearing capacity at elevated temperatures of transversely loaded beam sections laterally restrained by trapezoidal sheets and sandwich panels are being investigated.

WP3 - FULL-SCALE FURNACE TESTS

Schematic section of Roof Beam under test



WP3 - FULL-SCALE FURNACE TESTS

Roof Beam under test **SHS – Czech Republic, HEA- Finland**

WP3 - FULL-SCALE FURNACE TESTS

Failure can be of the member or the connection, as in the photograph below

STABFI – WORK PACKAGE 4

Slide 30/54

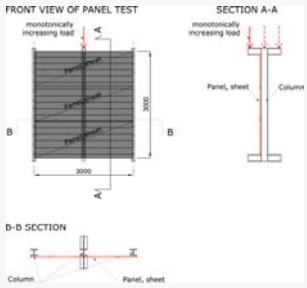
WP4 - TESTS IN NORMAL CONDITIONS SIMULATING FIRE

To observe in tests the resistance of a member when cladding is at an elevated temperature. Tests will be on both I- and tubular sections. In all 18 tests are planned.

To obtain experimental data of the temperatures of components at the joints of claddings to steel members in different structural arrangements. Heating is by electrical elements.

WP4 - TESTS IN NORMAL CONDITIONS SIMULATING FIRE

Test arrangement:



WP2, WP3 AND WP4 – CURRENT STATUS

First tests have been conducted.

Problem identified: PIR (Polyisocyanurate) produces plenty of smoke.

STABFI – WORK PACKAGE 5

Slide 34/54

WP5 - FEM MODEL DEVELOPMENT AND VALIDATION

Simulation of panels and joints in fire, comparison and verification with experimental results.

Analysis of experimental and simulated results, proposing simplified panel and joint elements.

Work Package leader:
Brandenburg University of Technology, Cottbus, Germany

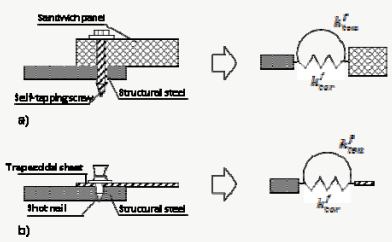
WP5 - FEM MODEL DEVELOPMENT AND VALIDATION

Numerical simulation of temperature fields in fire of the structure from WP2-WP4, and study of the stability and load bearing capacity of beams and columns under fire conditions using FEM.

Parametric Study: different geometries of trapezoidal sheeting and sandwich panels.

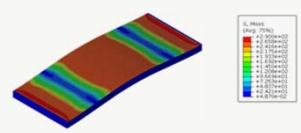
WP5 - FEM MODEL DEVELOPMENT AND VALIDATION

Typical FEM simulation:



WP5 – CURRENT STATUS

Preliminary FEM modelling of sandwich panels and joints has been done.
One problem that has been identified is that material data of mineral wool and PIR at elevated temperatures, required for FEM modelling, is difficult to obtain.



STABFI – WORK PACKAGE 6

Slide 39/54

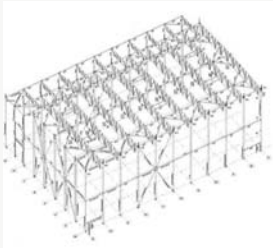
WP6 - BUILDING STABILIZATION USING SANDWICH PANELS

Structural bracing by sandwich panels and trapezoidal sheeting for one-storey industrial building at ambient temperature.

Develop FE models and study the fire resistance behaviour of individual structural members stabilized by sandwich panels and trapezoidal sheeting under ISO fires.

WP6 - BUILDING STABILIZATION USING SANDWICH PANELS

Schematic of building modelled:



WP6 - DELIVERED

D6.1 Stabilization of individual structural members at ambient temperature

Analysis and design of the building frame in room temperature using existing recommendations has been carried out.

New analytical expressions for member stabilisation with cladding have been derived.

STABFI – WORK PACKAGE 7

Slide 43/54

WP7 - DESIGN RULES, GUIDES AND SOFTWARE

Responsible institution: City, University of London.

The key objective is to adapt existing design rules, for the stabilisation of buildings using sandwich panels for the non-fire state, to the fire limit state.

Included in the design guide would be recommendations from WP1 on natural fires for different scenarios: walls, roof, as well as whole buildings.

WP7 - DESIGN RULES, GUIDES AND SOFTWARE

To validate the rules developed for the fire limit state by comparison with experimental and numerical results.

To develop a design guide, covering the new design rules as well as on the use of new software.

To write software for easy application of the new design rules.

WP7 – CURRENT STATUS

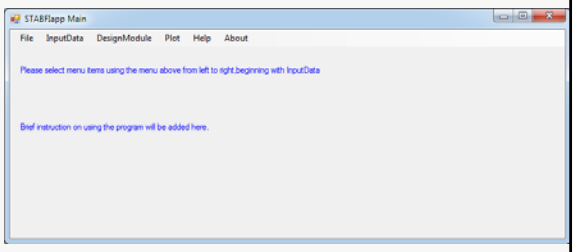
The system design of the software is being carried out.

Language VB2017

Compiled version would be available freely.

WP7 – CURRENT STATUS

Input Data screen looks like this:



STABFI – WORK PACKAGE 8

Slide 47/54

WP8 - DISSEMINATION

To disseminate the result of the project for public and for ECCS and Eurocode committees.

To organize workshops in 4 participating countries, Finland, Germany, Hungary and Czech Republic.

STABFI – WORK PACKAGE 9

Slide 49/54

WP9 - COORDINATION

Coordination and management of all the activities within the STABFI project.

APPLICATION FOR EU GRANTS

Slide 51/54

WP6 – KEY FACTORS FOR SUCCESSFUL APPLICATIONS

A good research project!	Fire part was wanted
Support from Industry	Ruukki, Kingspan, SFS
Assembling capable Team	Through Networking
Preparation	Idea at a METNET meeting
Before the application	Meeting in Berlin
Application preparation	Extensive e-mails
Knowledgable Leader	From Tampere

Answer all the requirements in the 'Call'

Hope for the best!

CONCLUSION

Slide 51/54

CONCLUSION

The project is progressing on schedule.

Almost all the deliverables due by this time have been delivered. One has been delayed by 3 months.

The next progress meeting is scheduled for August 2019 at City, when we hope to give a demonstration of the new software – at least for ambient conditions.

THANK YOU

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