1.4 Behaviour of aluminium alloy structures in fire (short version)

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BEHAVIOUR OF ALUMINIUM ALLOY STRUCTURES IN FIRE

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OBJECT

Design of structures made of aluminium alloys exposed to fire

MOTIVATION

Better understanding of the mechanical behaviour of aluminium alloys used for civil constructions under high temperatures

AIM

Influence of the peculiar mechanical properties of aluminium alloys in fire on the resistance of structural elements (beam, column, joints, ...)

LAYOUT OF THE PRESENTATION

- Codification overview
- Mechanical properties of aluminium alloys in fire according to EC9
- Set up of more appropriate mechanical models
- Structural analysis under fire of a typical structure (e.g. portal frame)

- State of the art overview

CODIFICATION

European standards for fire design of metal structures

EC 1 – Part 2-2, Action on structures under fire;

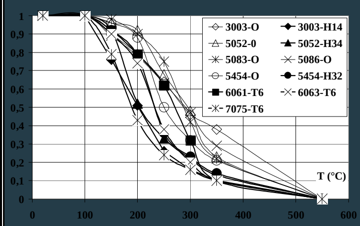
EC 3 – Part 1-2, Steel structures exposed to fire;

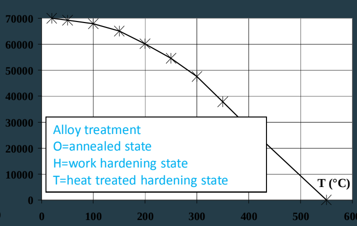
EC 9 – Part 1-2, Alluminium alloy structures exposed to fire.

Whilst existing codes are COMPREHENSIVE, HANDLY AND RELIABLE for the most common material for constructions (steel and reinforced concrete), for aluminium alloys, prposed formulations and methods are approximate. Considering that **ALUMINIUM IS HIGHLY VULNERABLE AGAINST FIRE**, more refined models of the mechanical behaviour is required, in order to consider the full capacity of the material

- Examination of the mechanical properties under fire of the EC9 aluminium alloys

MECHANICAL PROPERTIES AT HIGH TEMPERATURES - EC9 MODEL



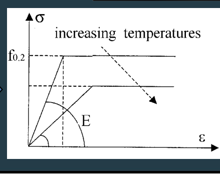


Reduction coefficient of the conventional yielding stress $k_{0.2,T}$

$f_{0.2,T} = k_{0.2,T} * f_{0.2}$

Young modulus E_T (N/mm²)

Eurocode 9 provides $k_{0.2,T}$ and E_T



Ideal elastic-plastic material model

- Set up of a mechanical model at high temperatures

σ–ε CONSTITUTIVE LAWS FOR ALLUMINIUM ALLOYS AT AMBIENT TEMPERATURE

The mechanical modelling of the aluminium alloys is complicated (also at ambient temperature)

- several alloys with really different mechanical features
- the material behaviour is not characterized by a clear yielding and has a not-negligible non linear behaviour especially for large deformations

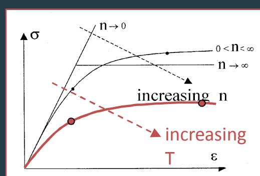
σ–ε relationship cannot be interpreted by a simplified elastic-perfectly plastic behaviour

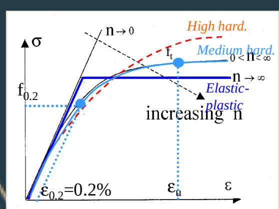
- Set up of a mechanical model at high temperatures

σ–ε CONSTITUTIVE LAW FOR ALLUMINIUM ALLOYS AT AMBIENT TEMPERATURES

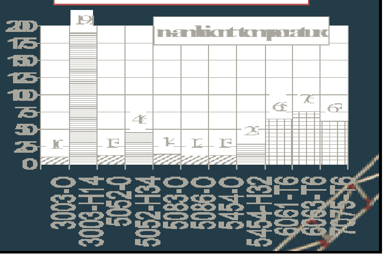
Ramberg-Osgood model

$$\varepsilon = \frac{\sigma}{E} + 0.002\left(\frac{\sigma}{f_{0.2}}\right)^n \quad \text{with} \quad n = \frac{\log \frac{0.002}{\varepsilon_u}}{\log \frac{f_{0.2}}{f_t}}$$



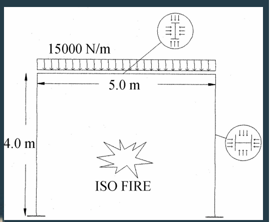


The strain hardening factor *n* at ambient temperature



➢Structural analysis of a portal frame under fire

STRUCTURAL ANALYSIS IN FIRE OF A SIMPLE PLANE PORTAL FRAME MADE OF DIFFERENT ALUMINIUM ALLOYS

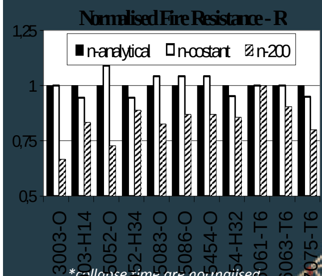


ALLOY	$f_{0.2,d}$ (N/mm²)	Column	Beam
3003-O	45	HEB160	IPE450
3003-H14	145	HEB160	IPE300
5052-O	90	HEB160	IPE330
5052-H34	215	HEB160	IPE240
5454-O	117	HEB160	IPE300
5454-H32	207	HEB160	IPE240
5083-O	145	HEB160	IPE300
5086-O	117	HEB160	IPE300
6061-T6	283	HEB160	IPE240
6063-T6	220	HEB160	IPE240
7075-T6	517	HEB160	IPE240

➢Structural analysis of a portal frame under fire

STRUCTURAL ANALYSIS IN FIRE CONDITION OF A SIMPLE PLANE PORTAL FRAME MADE OF DIFFERENT ALUMINIUM ALLOYS

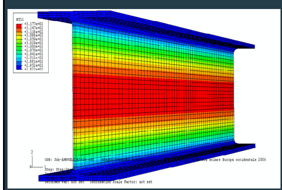
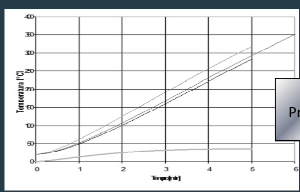
ALLOY	*Normalised FIRE RESISTANCE**		
	n-analytical	*n-constant*	*n-200*
3003-O	*1*	*1*	*0.67*
3003-H14	*1*	*0.9*	*0.83*
5052-O	*1.2*	*1.33*	*0.87*
5052-H34	*1*	*0.9*	*0.87*
5083-O	*1.23*	*1.33*	*1.03*
5086-O	*1.23*	*1.33*	*1.07*
5454-O	*1.23*	*1.33*	*1.07*
5454-H32	*1.17*	*1.07*	*1*
6061-T6	*0.87*	*0.87*	*0.87*
6063-T6	*1.17*	*1.17*	*1.03*
7075-T6	*1.07*	*1.03*	*0.87*



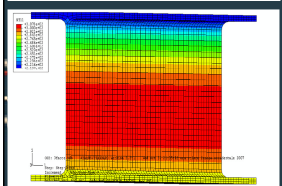
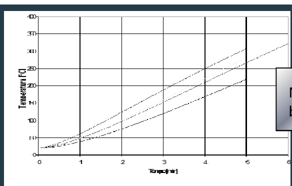
**collapse time are normalised respect to the minimum value (A 3003-O)*

➢Sophisticated FEM analyses for members response under fire

IPE 300 exposed on four faces

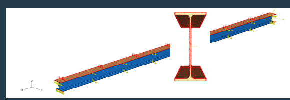
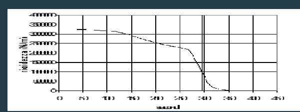
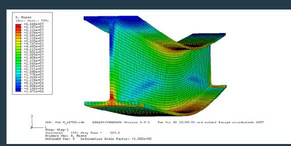
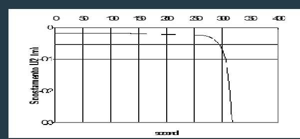
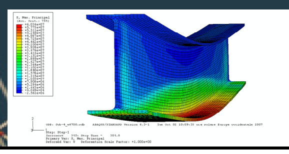
Protected beam

Not Protected beam

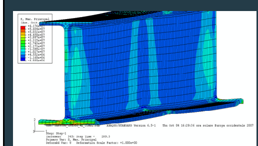
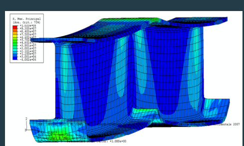
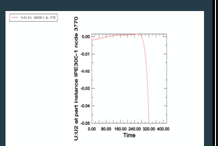
➢Sophisticated FEM analyses for members response under fire

IPE 300 exposed on four faces

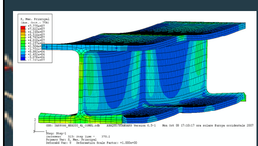
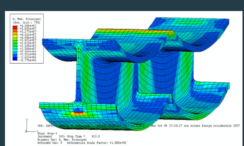
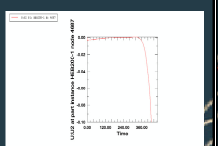







➢Sophisticated FEM analyses for members response under fire

IPE 300 on three supports exposed on four faces

HEB 200 on three supports exposed on four faces

➢Sophisticated FEM analyses for members response under fire

Buckling Curves