

## The correct value of the fire and the observing of the effects of the fire-extinguisher system

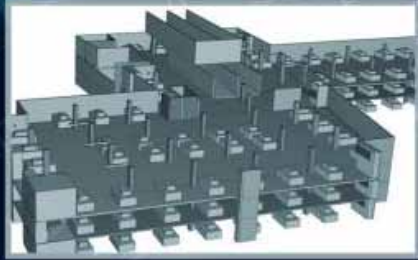
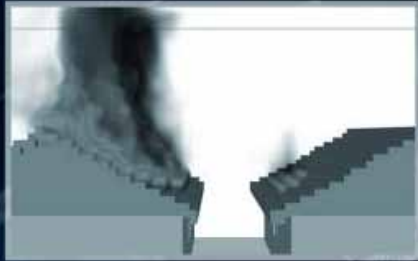
WG3 – Csaba Szilágyi, [sz.csaba@optomm.hu](mailto:sz.csaba@optomm.hu)



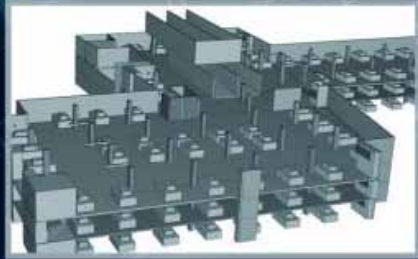
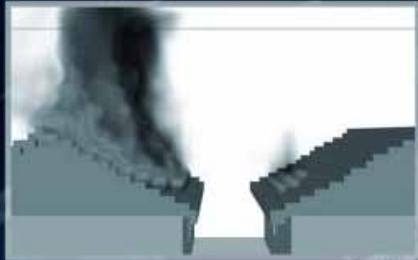
## Why is it important?

According to EC you can use the CFD model like FDS. If you calculate your structure, according to a CFD simulation. It's really important that you use well this tool.

- Correctly the fire size (area sm)
- Correctly the heat release rate (kW)
- Correctly the smoke and heat exhaust system (if there is)
- Correctly the suppression system (if there is)
- Such as important that you use well the EC calculation to the structure
- If you calculate wrong input parameters the result will be totally fault.



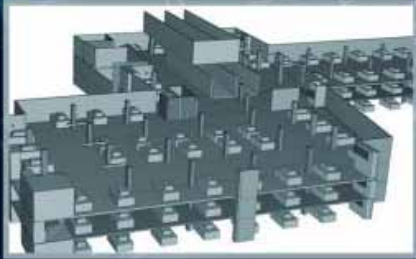
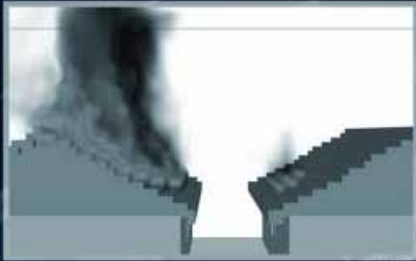
## Fuel sources in FDS



In an FDS model we can use two main type of a fuel source.

- we use the pyrolysis model according to kinetics parameters, and physical and chemical properties
- we use a predefined HRR curve according to different calorimeters, or products of mass flow and heat of combustion

# Pyrolysis

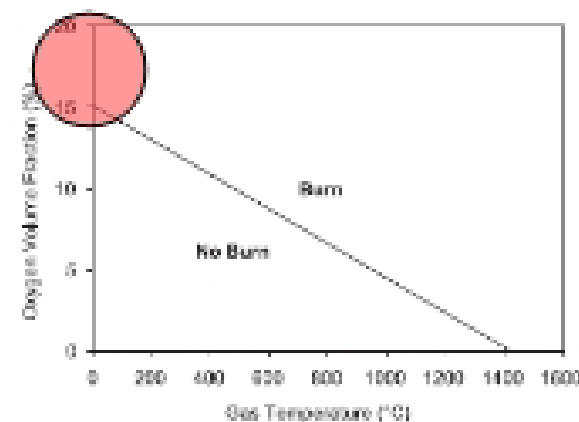


- Decomposition by heat
- It means mass decreasing
- It means the fuel ( material which is able to burn) leave the surface
- It doesn't mean flames
- Need the fire triangle for the burning (oxygen, ignition temperature, fuel)

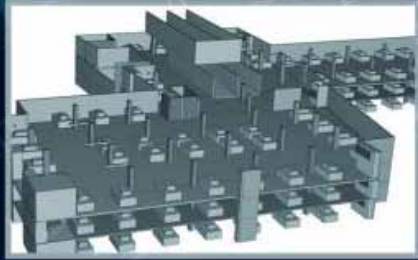
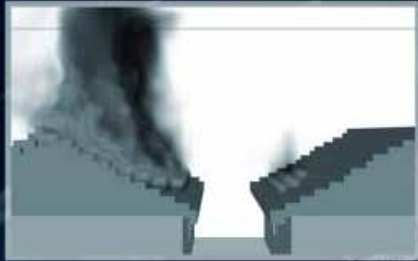
## Predefined HRR

- HRR means heat release rate from the combustion material. The most simple data from a cone calorimeter
- Alternative source can be the product of mass flow and heat of combustion
- In the FDS if you use this property at a material, you will give a fuel flow from the surface which can increase the value of the HRR
- It means a fire because of in the FDS the burning depend on according this figure

(The source: NIST Special Publication 1019-5 Fire Dynamics Simulator (Version 5) Technical Reference Guide )



## Details of the Pyrolysis



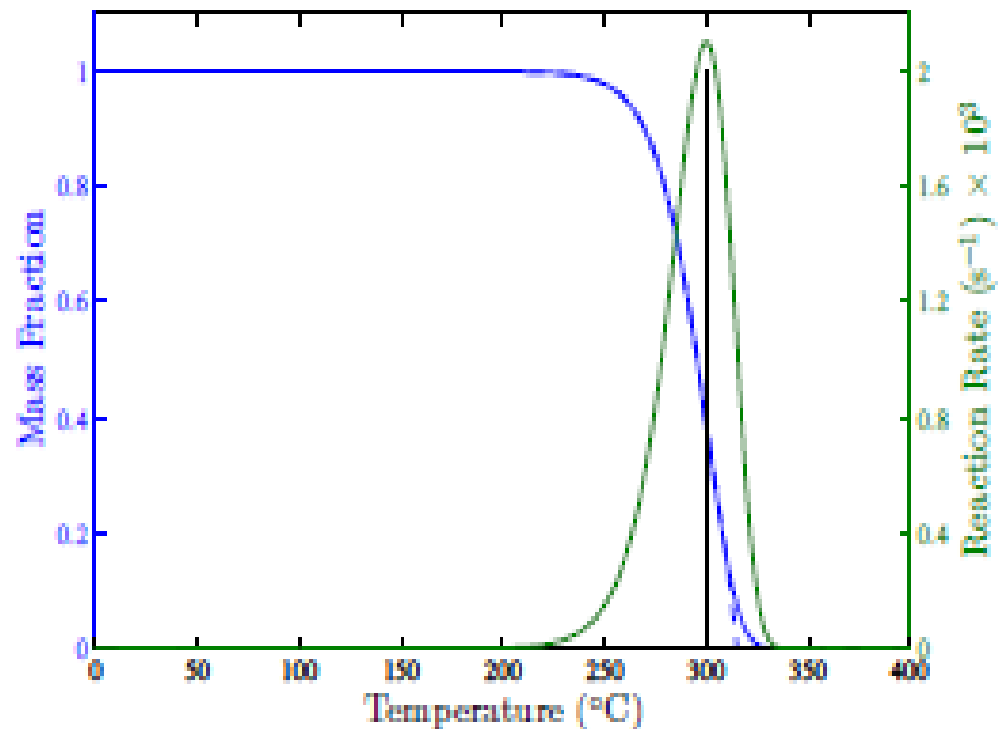
- The pyrolysis rate is given by an Arrhenius type expression
- Need the value of „A” pre-exponential factor and „E” activation energy
- It can be difficult at composite materials.

$$\dot{m}'' = A \rho_s e^{-E_A/RT}$$

# Details of the Pyrolysis

- In the FDS we can use practical simplification
- The FDS calculate A and E from a TGA curve or from an estimated TGA curve.

The source: NIST Special Publication 1019-5 Fire Dynamics Simulator (Version 5) User's Guide



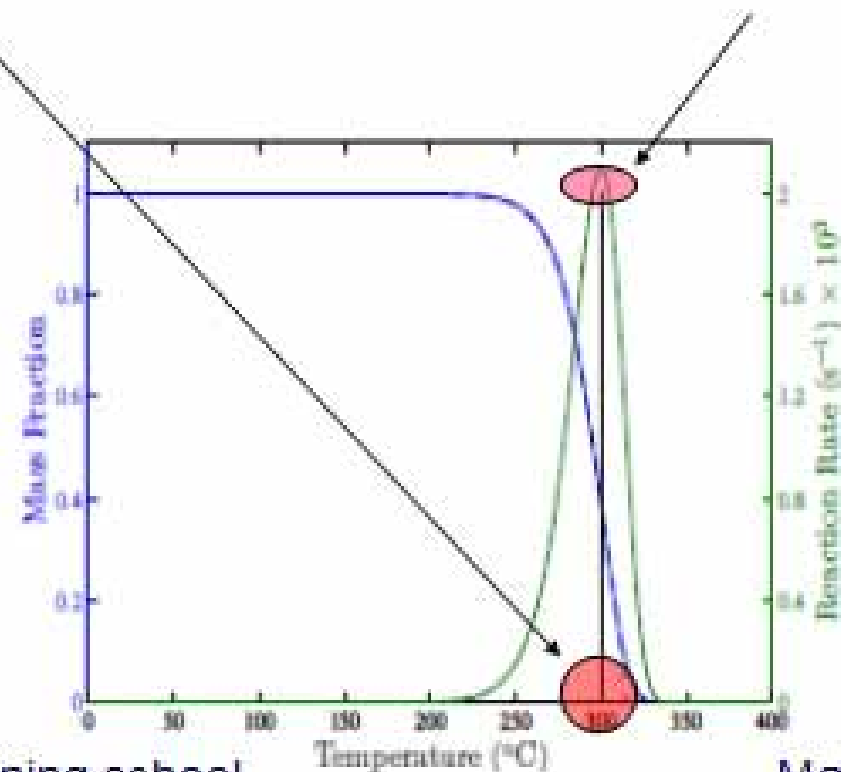
## Details of the Pyrolysis TGA curve is reachable

- Reference temperature like the temperature where there is the maximum of the rate of the mass loss
- Reference rate like the maximum of the rate of the mass loss

The source: NIST Special Publication 1019-5 Fire Dynamics Simulator (Version 5) User's Guide

Reference temperature

Reference rate





# Details of the Pyrolysis

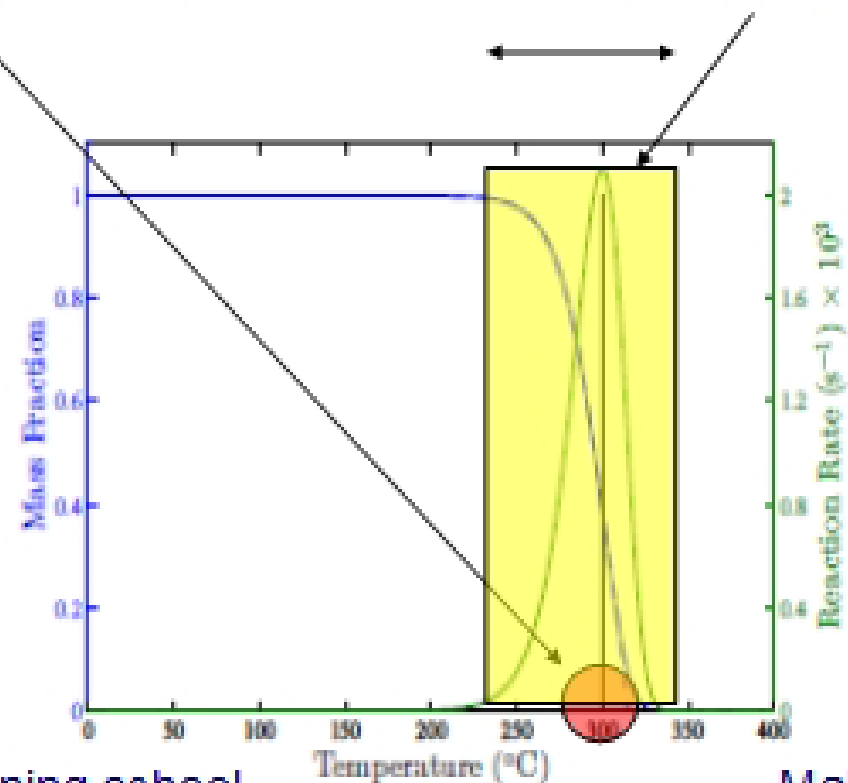
## TGA is just estimated

- Reference temperature which is from an estimation
- Pyrolysis range is also an estimated. That means the width of the range

The source: NIST Special Publication 1019-6 Fire Dynamics Simulator (Version 5) User's Guide

Reference temperature

Pyrolysis range

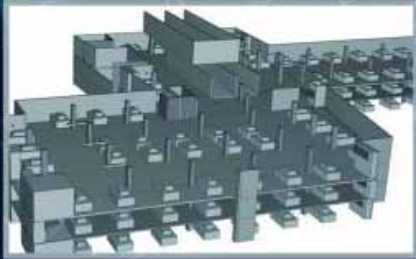
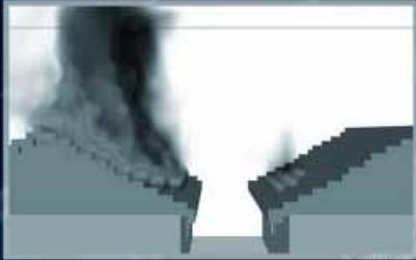


# Composite materials

- We have applicable sources from the pure materials
- The sources are poorly if we need TGA curves from composite materials.
- Perfectly poorly if we prefer A and E
- In a real environment in a building the most of the materials are composite



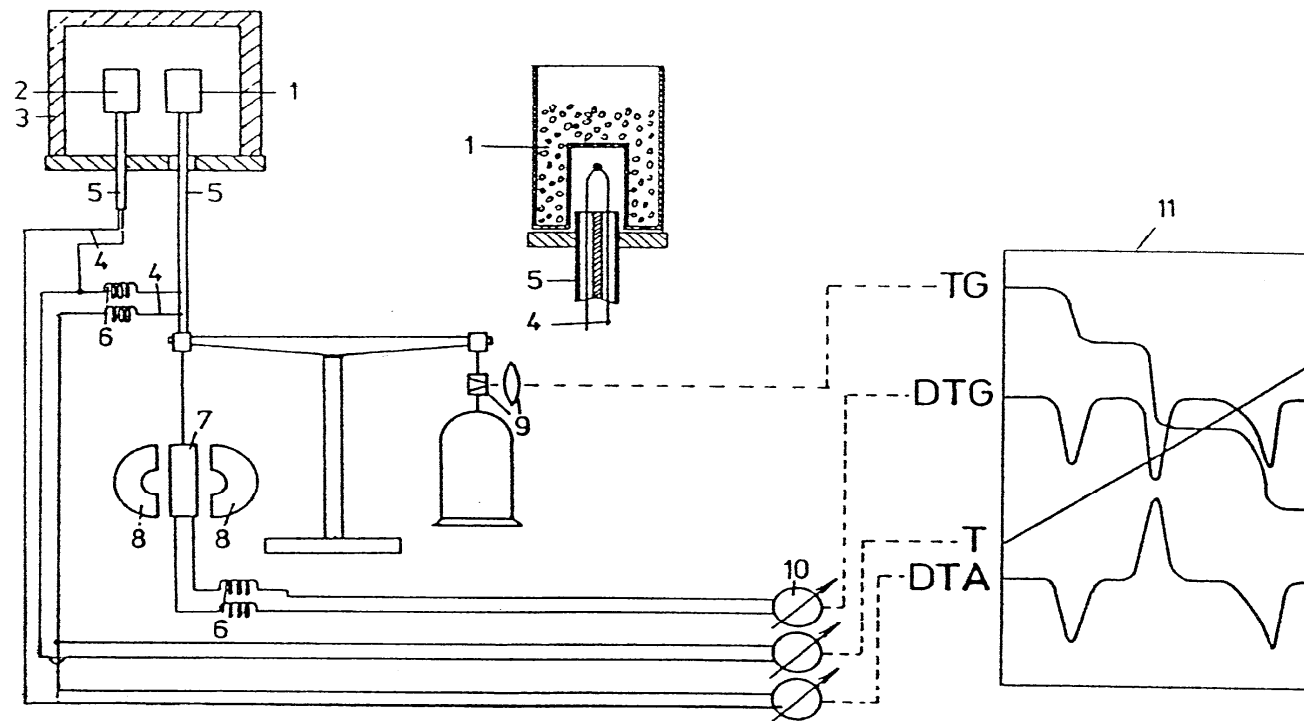
# Composite materials



- We need to use the first order reaction. Because we haven't got information from the composite materials.
- That's why we have researched the properties of different materials with László Beda, (Ybl Miklós Faculty of Building Sciences)

# Derivatograph

In our work, we used *Derivatograph Q 1500D* which is an instrument for simultaneous TG, DTG, DTA and TA investigations, using non-isothermal, isothermal and quasi-isothermal heating techniques. The samples were heated in *Derivatograph Q 1500D* in an inert atmosphere ( $67\text{ml min}^{-1}$  Nitrogen) at a temperature range of  $25\text{-}1000^\circ\text{C}$  with linear heating rate of  $10^\circ\text{C min}^{-1}$ . The weight loss (TG), the differential thermo-analytical curve (DTA) and the temperature changes (T) were recorded as a function of time. From the results the rate of conversion ( $\alpha$ ) was calculated and the mass and rate of conversion were plotted as a function of temperature.



**Fig. 3.1.1** Derivatograph for simultaneous TG, DTG and DTA.

1) Sample; 2) reference material; 3) furnace; 4) thermocouples; 5) corundum tubes; 6) flexible junction; 7) coil; 8) magnet; 9) optical system; 10) galvanometers; 11) photographic paper

# Derivatograph

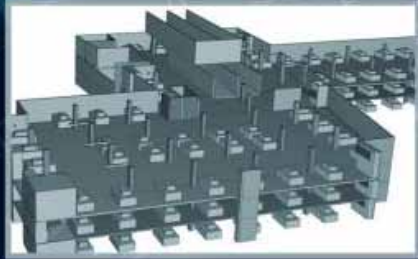
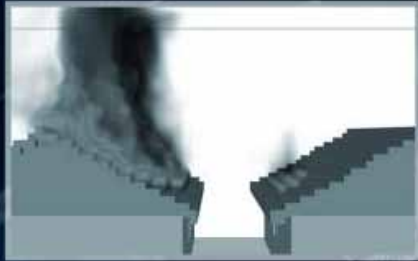
We analysed :

*Pine Wood Board (PWB)*

*Multi-layered Parquet Board (MPB)*

*Particleboard Core (PBC),*

*Oriented Standard Board (OSB)*



*Pine Wood Board (PWB)*



*Multilayered Parquet Board (MPB)*

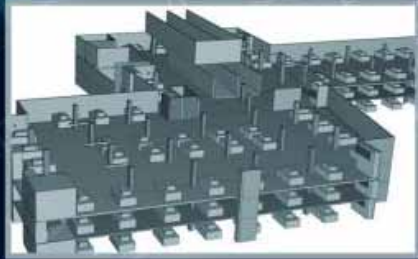
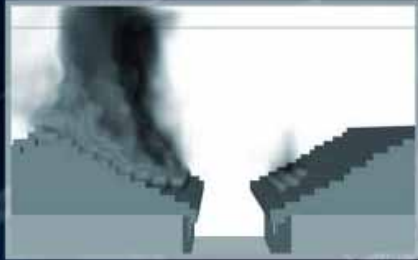


*Particleboard Core (PBC),*



*Oriented Standard Board (OSB)*

## Derivatograph



*The sample parameters were as follows:*

*Pine Wood Board (PWB): sample size – 120,0 mg,  
residue – 8,6 mg*

*Multi layered Parquet Board (MPB): sample size – 149,9 mg,  
residue – 35,5 mg*

*Particleboard Core (PBC), – 132,0 mg, residue – 19,3 mg*

*Oriented Standard Board (OSB) – 90,0 mg, residue – 1,0 mg*

*The composition of MPB, PBC, and*

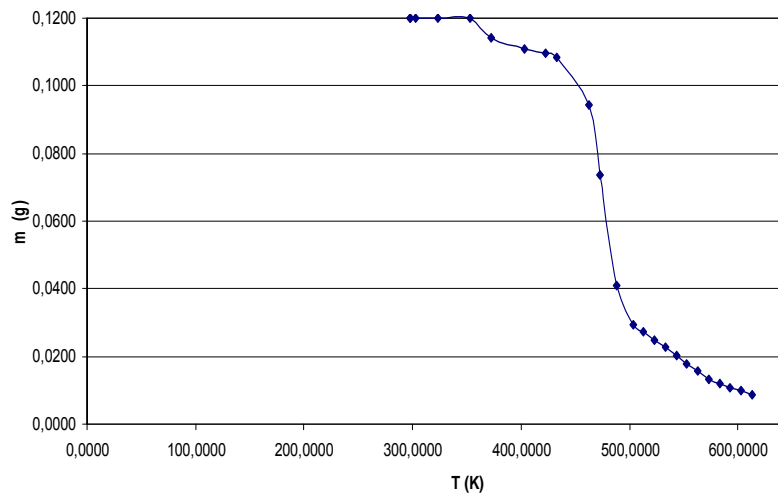
*OSB: approximately 90-95% wood,  
10-5% carbamide-phenol-formaldehyde resin.*

*Prior to the experiments the samples were stored in  
room temperature (25 °C, 50 % relative humidity)  
for two weeks.*

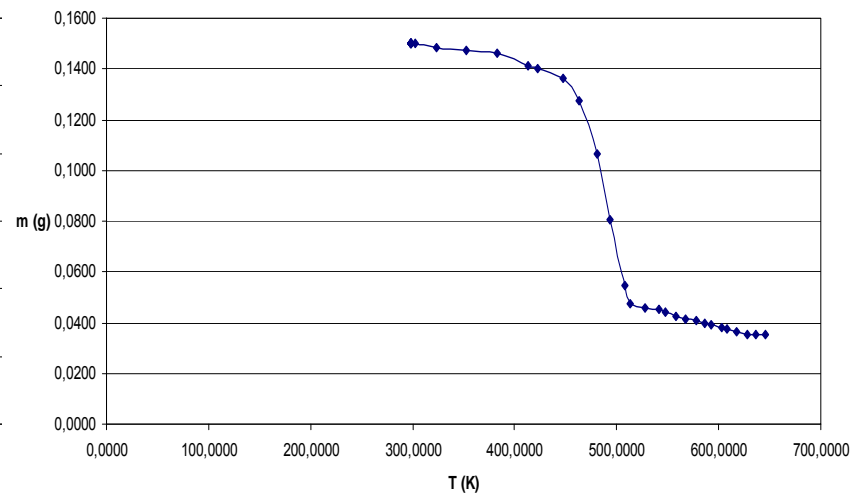
# Derivatograph

## mass-temperature diagrams

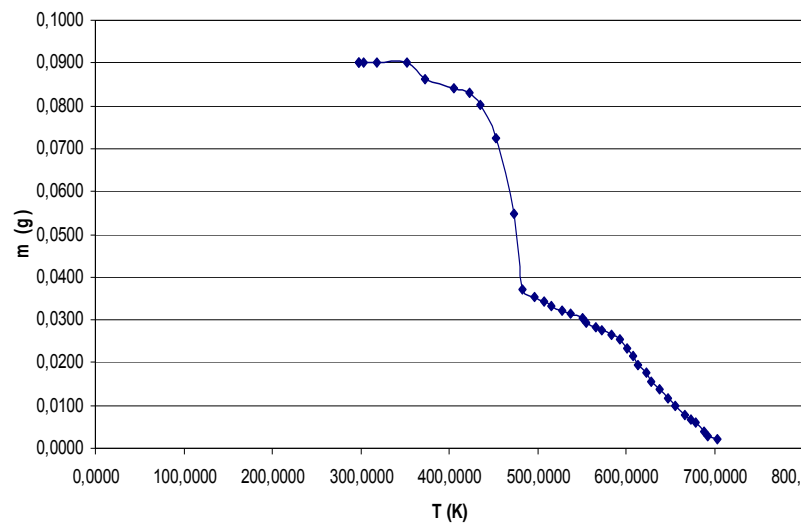
PWB mass - temperature



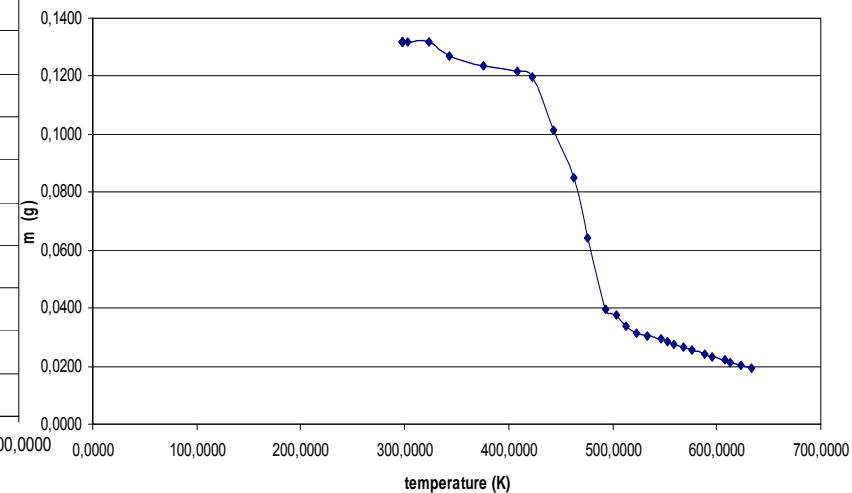
MPB mass-temperature



OSB mass-temperature



PBC mass - temperature



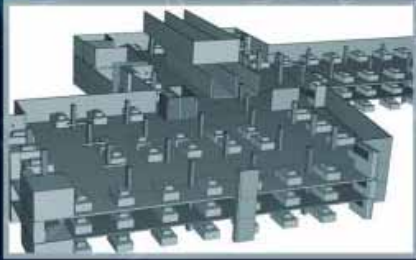
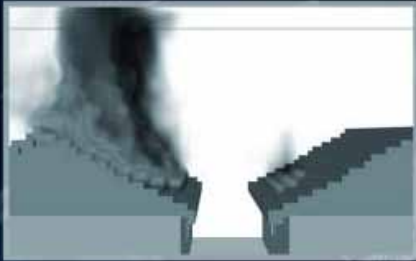
# Derivatograph

The TG curves indicate the temperature regimes of decomposition. The results are summarized in *Table*

Decomposition stages	Sample			
	PWB	MPB	PBC	OSB
Elimination of moisture (°C)	80-130	80-140	80-180	80-150
Active decomposition (°C)	190-240	180-250	190-240	190-260
Pyrolysis (°C)	240-330	270-360	260-340	270-390



# Conversation



$$\frac{d\alpha}{dt} = A e^{-\frac{E}{RT}} (1 - \alpha)$$

$$\alpha = \frac{\Delta m_t}{\Delta m_\infty}$$

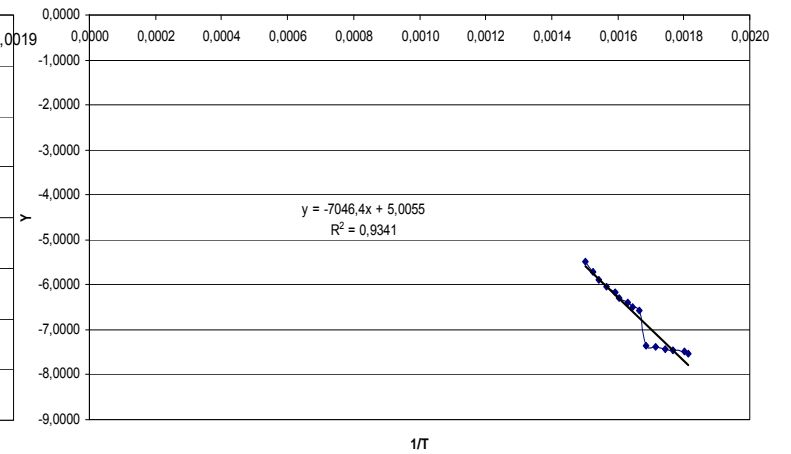
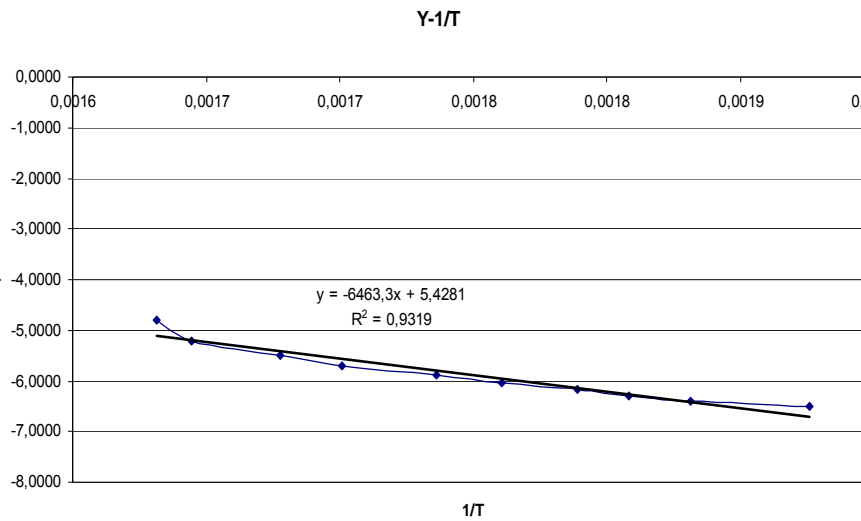
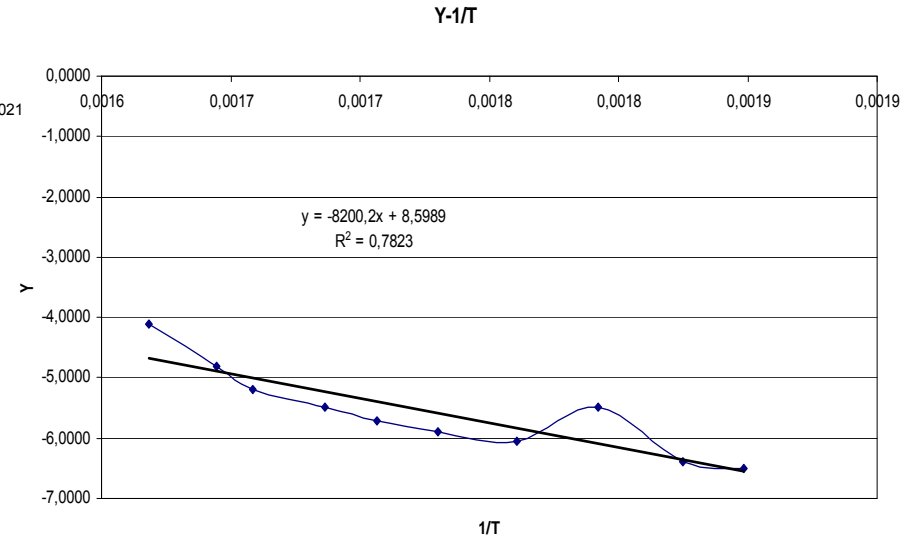
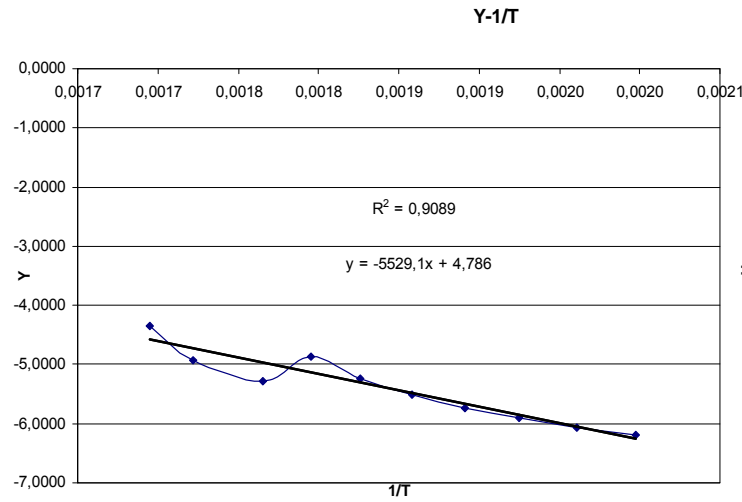
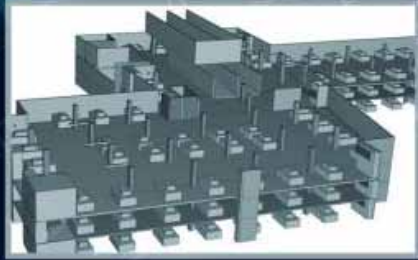
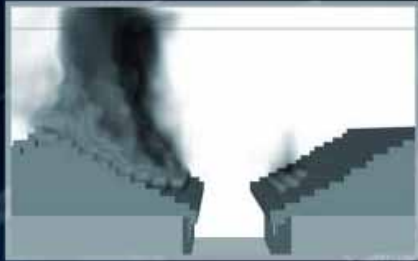
$$\ln \left[ \frac{d\alpha}{dt} \right] = \ln A - \frac{E}{R} \left[ \frac{1}{T} \right] + \ln (1 - \alpha)$$

$$\ln \left[ \frac{d\alpha}{dt} \right] = y \quad -\frac{E}{R} = p_2 \quad \frac{1}{T} = x$$

$$y = p_1 + p_2 x + \ln (1 - \alpha)$$

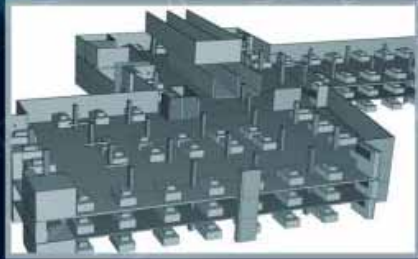
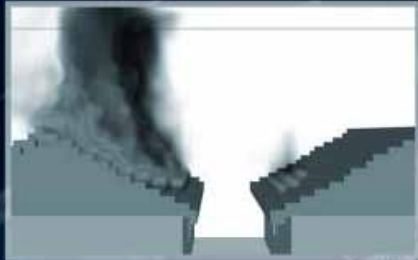
$$y - \ln (1 - \alpha) = Y = p_1 + p_2 x$$

# Derivatograph



# Derivatograph

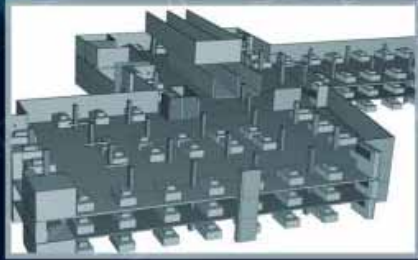
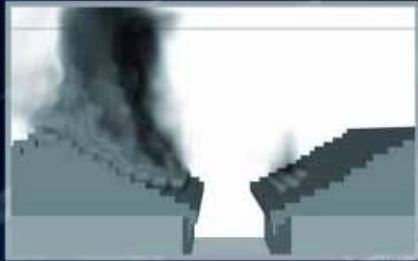
## mass-temperature diagrams



	Equation	E (kJ/mol)	A (1/min)	R <sup>2</sup>
PWB	$y = -5714,7x + 4,8613$	47,5	$7,752 \times 10^3$	0,9089
MPB	$y = -8200,2x + 8,5989$	68,2	$3,255 \times 10^5$	0,7823
PBC	$y = -6463,3x + 5,4281$	53,7	$1,366 \times 10^4$	0,9319
OSB	$y = -7048,4x + 5,0055$	58,6	$8,954 \times 10^3$	0,9341

# Pyrolysis

- The size of the different materials have effect to their ignition
- The heat capacity of a little size material is also smaller than a larger size material's.
- The pyrolysis can be more intensive, because a small size material has larger surface rate.



# FDS suppression

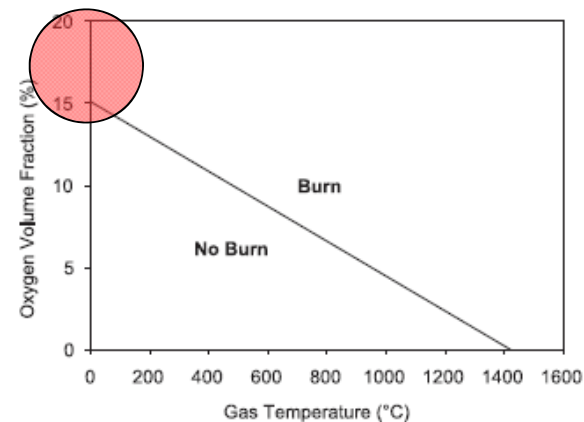
$$\dot{m}''_f(t) = \dot{m}''_{f,0}(t) e^{-\int k(t) dt}$$

$$k(t) = E\_COEFFICIENT \dot{m}''_w(t) \text{ s}^{-1}$$

In the FDS the water reduces the pyrolysis by heat loss. If we use a predefined HRR, the water won't reduce the pyrolysis. In this situation the fire is similar to a gas burner. The quantity of the fuel will be the same, with water and without water in the model space.

If there are fuel and oxygen in a normal environment, there will be a fire in FDS according to this figure:

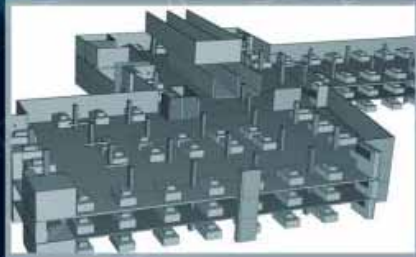
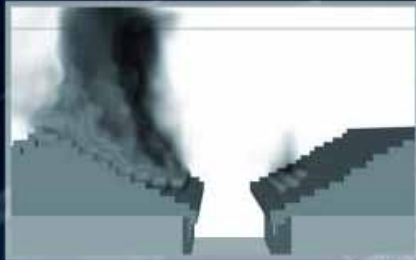
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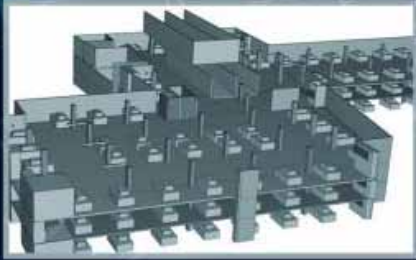
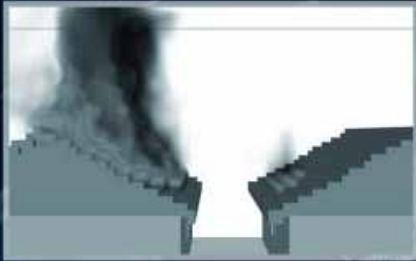
# FDS suppression

The FDS isn't capable to analyse precisely the fire damages. The water can't flow between the surfaces, and can't suppression like in the „real” world.

For example: on the left picture the material is collapsed like a wood furniture in a fire, but on the right side the material doesn't collapse.



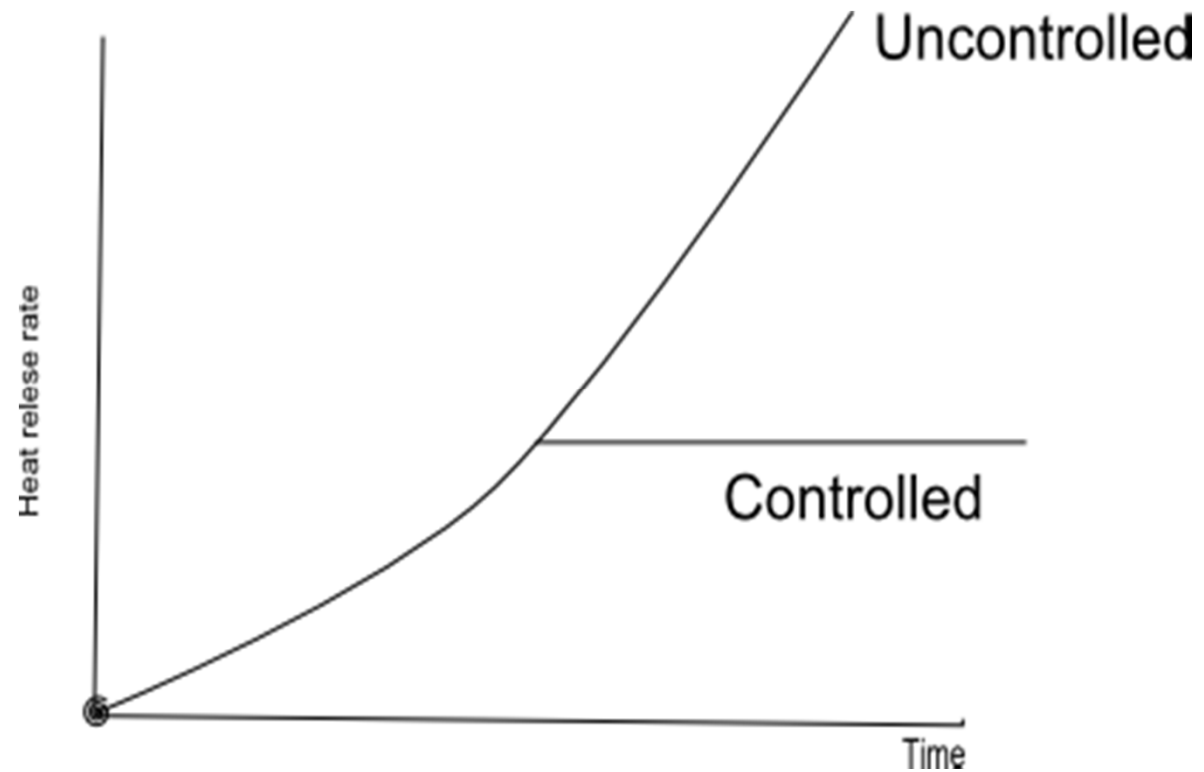
# Fire



- first scene to use a combustion material,  
For example: with A,E values and you use  
the suppression calculation from FDS.
- second scene to use a predefined HRR curve where  
you calculate the effect of the fire suppression system.

# Fire

- Effect of the suppression system. You can calculate according to BS PD 7974:2003

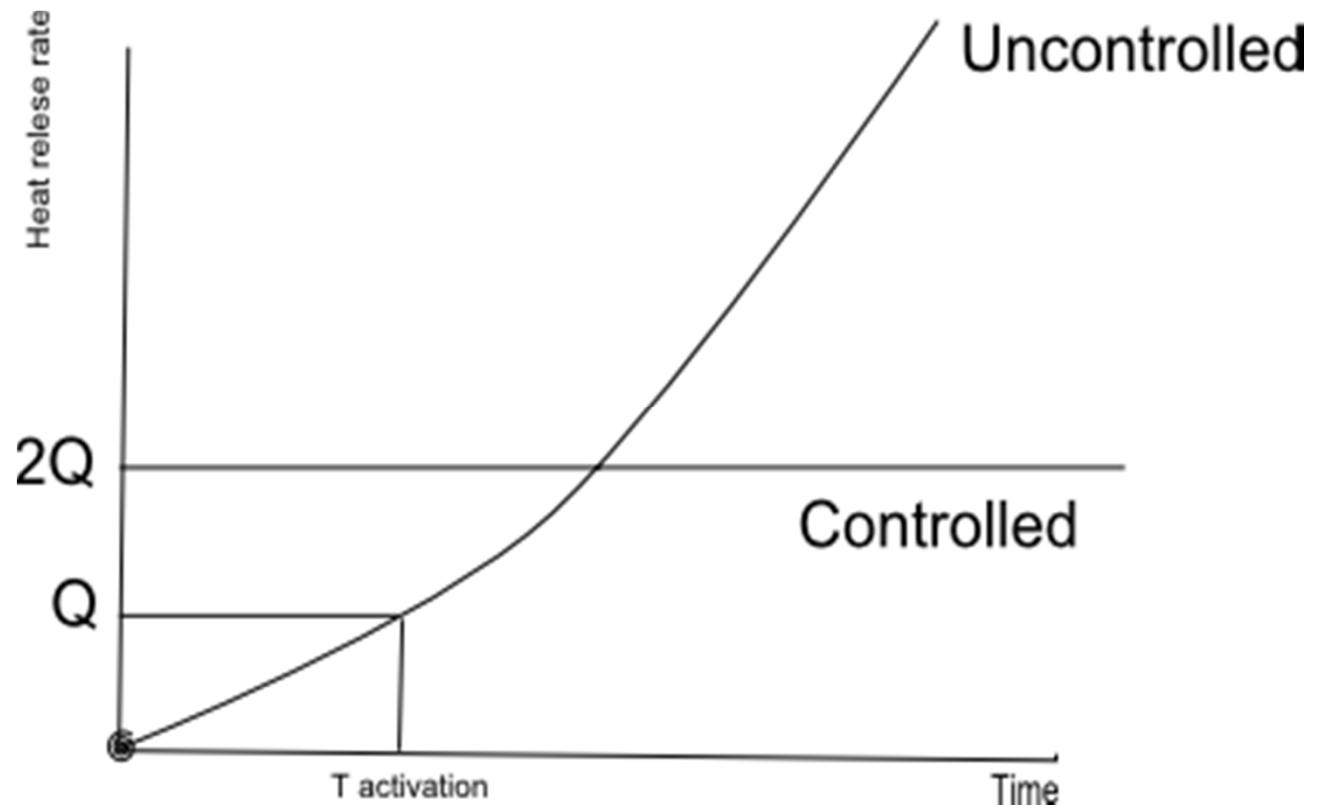




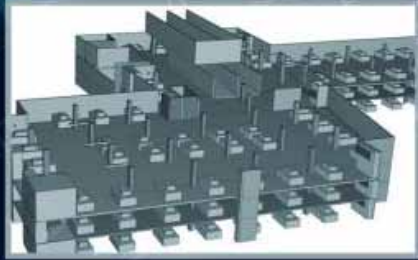
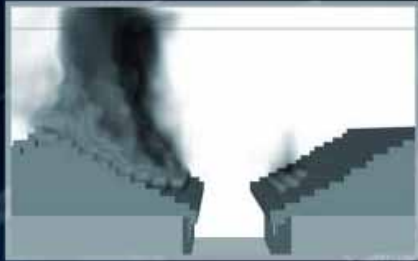
# Fire

- An alternative calculation of effect of the suppression system.  
You can calculate according to VTT Jukka Hietaniemi & Esko Mikkola  
Design Fires for Fire Safety Engineering 2010

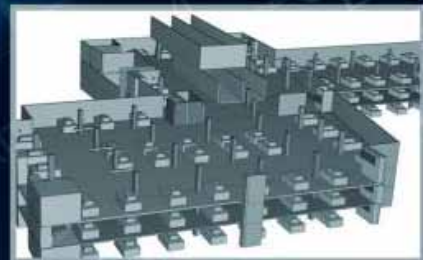
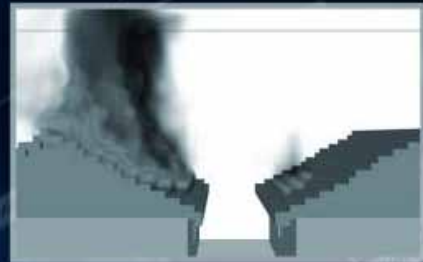
1. Calculate the activation time
2. Look at what is HRR at the activation time.
3. The design HRR, is obtained by doubling this value, and the fire is assumed to burn on the design HRR until the end of calculation



# Fire



- An interesting question can be:  
If we use the effect of the water suppression system in the predefined HRR curve, can we use the sprinkler heads in the same space in the same time, or in this case we calculate twice the effect with the water suppression.
- In the FDS when we use predefined HRR curve the water doesn't reduce the process of the pyrolysis, the fuel will burn in the space if there is enough oxygen ( like in a well ventilated area) , in this situation we don't calculate twice the effect of the water.
- These situations are really important, when we calculate in EC with a temperature curve which derive from an FDS model



**THANK YOU FOR YOUR ATTENTION**