Effect Of Different Mfft Values On Fire Resistance Time In Water Based Intumescent Coatings

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Passive Fire Protection for Structural Steel

Passive Fire Protections allows Safe Escape

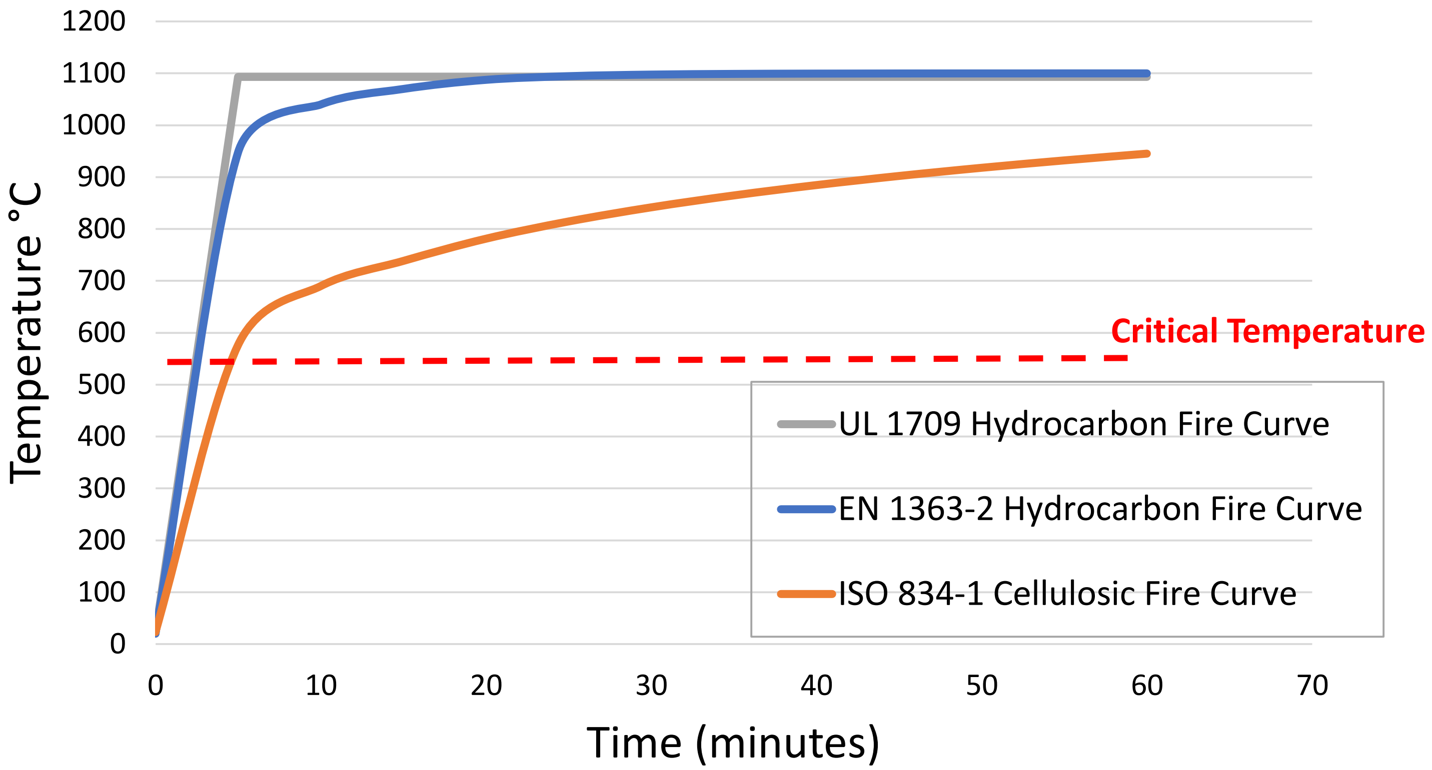
→ Passive Fire Protection (PFP) prevents structural collapse and allows safe escape in combination with active fire protection

→ Prevents collapse between 30 minutes to 180 minutes depending on the building type.

Passive Fire Protection has several methods for providing fire resistances to structural steels

Intumescent Coatings

Passive Fire Protection for Structural Steel



Fire Curve for Cellulosic Fire and Hydrocarbon Fires

European regulations and guidelines

European Technical Assessments (ETA) defines the ‘Reactive Coatings for Fire Protection of Steel’ in **EAD 350402-00-1106** since 2017. According to regions, regulations can change.

Product Group	Description	European Standards	European Product Standards or EADs	North American Requirements	British Standards
Structural steel members (including the contribution of the applied protection)	Reactive protection to steel members	EN 1365 EN 13381-8	ETAG 018 EAD 350402-00-1106	UL 263 UL 1709 ASTM E119	BS 476: Part 21& ASFP Yellow Book 5th Edition

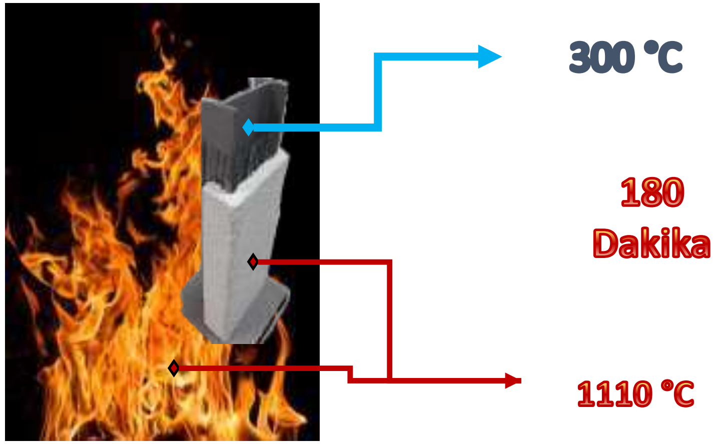
Passive Fire Protection for Structural Steel

During the Fire, Environment Temperature reaches to the 1050 °C during 120 minutes

→ In cellulosic fires, in 4-5 minutes, **Environment Temperature** reaches to 550 °C which is the general critical temperatures for steel structures.

→ During the fire, **Environment Temperature** reaches to more than 1000 ° C degree after 60 minutes acc. to ISO 834-1 Fire curve.

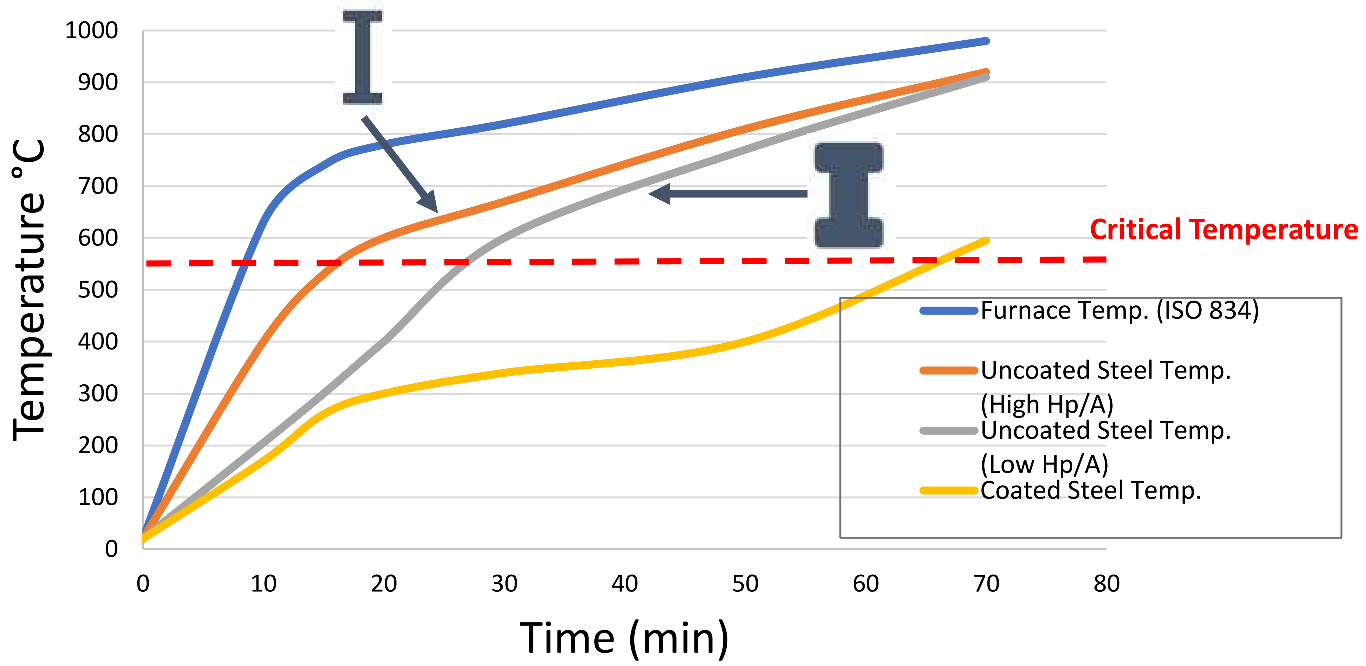
→ Passive Fire Protection ignores to reaching of critical temperature of steel structure (i.e. 450, 500, 550 or 600° C degree) and **expands the fire resistance** time till 180 minutes.



Time (min)	0	15	30	60	120	180	240	300	360
Environment Temperature (°C)	23	739	842	945	1050	1110	1150	1185	1215

Steel structures has very poor thermal conductivity performance and deliver its thermal energy to the conducted structures.

Passive Fire Protection for Structural Steel



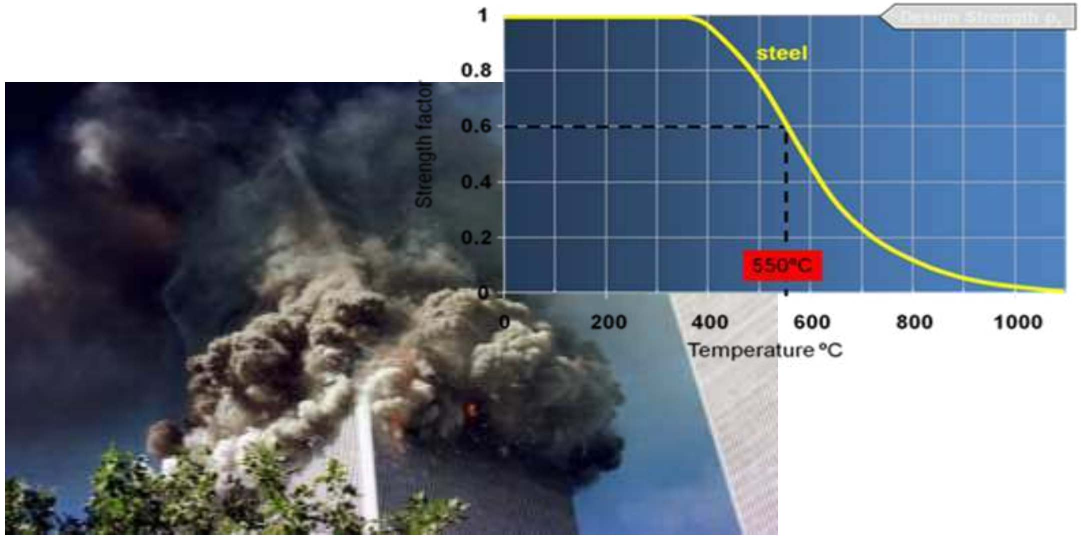
Fire Curve Differences of Coated and Uncoated Steel and Critical Temperature dyo

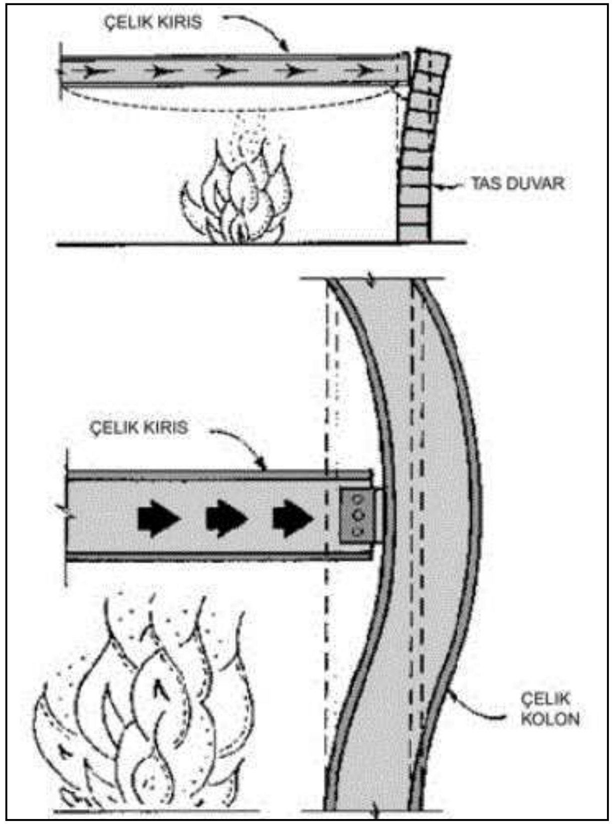
Passive Fire Protection for Structural Steel

Steel does not burn but has serious weakness

→ Strenght factor decreases with rising temperature

→ Reaching to 0.6 Strenght Factor at Critical Temperature, steel losses its %40 strenght and does not carry the building anymore.



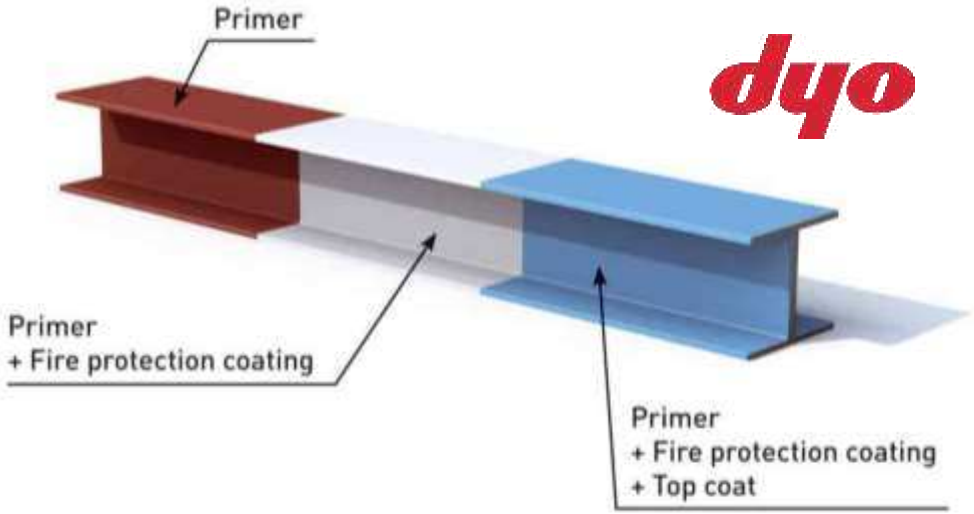


Intumescent Coatings is one of the passive fire resistances method that requires aesthetics view to structures.

Intumescent Coatings

Passive Fire Protection for Structural Steel

Commercial intumescents are usually applied in a 3 coat system



Under the influence of fire, the intumescent coating swells in a controlled manner to produce an insulating foam that protects the substrate from the effects of the fire and delays temperature increase

Unlike cementitious sprays or mineral boards, thin coatings preserve the aesthetics of the steel structure

Passive Fire Protection for Structural Steel

With an increased use of steel structures in construction, architects want to preserve the steel aesthetic of buildings

This has allowed **intumescent coatings to dominate the passive fire protection market** over the past decade

→ It is possible to have decorative intumescent coatings

→ Only intumescent coating can cover complex shapes

→ They can repair easily if damaged

European regulations and guidelines

EAD (European Assessment Document) 350402-00-1106 Standard covers the;

→ Durability performance of the coating

→ Coating system such as primer and top coat (if need),

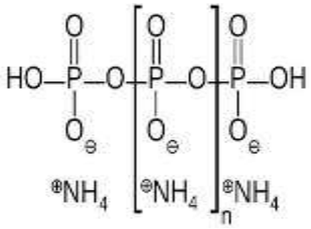
→ Standart for Fire resistance assessment

Type	Exposure Description
X	Renderings and rendering kits intended for all climatic conditions (internal, semi-exposed and exposed to weather)
Y	Renderings and rendering kits intended for internal and semi-exposed conditions. "Semi-exposed" includes temperatures below 0°C, but no exposure to rain and limited or casual exposure to UV (but the effect of UV exposure is not assessed.)
Z1	Renderings and rendering kits intended for internal conditions with humidity equal to or higher than 85% RH, excluding temperatures below 0°C.
Z2	Renderings and rendering kits intended for internal conditions with humidity lower than 85% RH, excluding temperatures below 0°C.

Intumescent Coating Components

Mineral Acid Source
Ex. Ammonium Polyphosphate

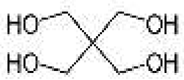
- → Catalyst
- → Contains high amount of phosphorous
- → Decomposes to phosphoric acid with heat decomposition
- → Decomposition starts around 250 °C and finishes around 600°C



Ammonium polyphosphate

Source of Carbon
Ex: Pentaerytritol

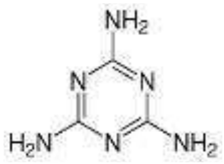
- → Carbonific
- → Polyhidric alcohol
- → Decomposition starts between 220°C and 260°C



Pentaerythritol

Blowing Agent
Ex: Melamine

- → Spumific
- → Decomposition product
- → Ex: melamine



Melamine

Binder is also a key element of the formulation

Intumescent Coatings

Thermal Analysis Stages

→ Stability Stage (20 – 230 °C) : The main lost components are volatilized solvents. Nearly 170°C, resin that melts and softens absorbs the energy.

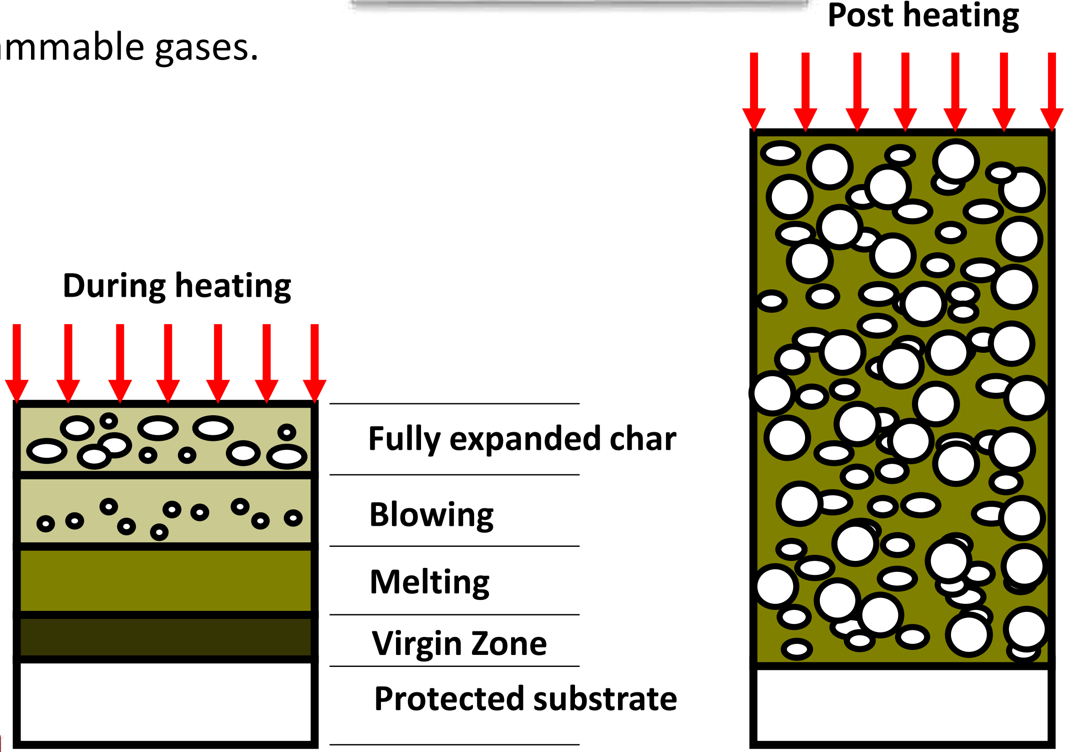
→ Formation of Char Layer Stage (230-450°C) :

- Acid source began to decompose at about 260°C.
- 280-350°C blowing agent decomposes and gave our large quantities nono-flammable gases.
- This cause to formation of a carbon-like foam layer over the substrate.

Carbon source dehydrated by acid attack through an esterification at 320-360°C.

→ Stage of Char Loss (455 – 760 °C) : Char layer caused to the heat absorbtion. Network density between char layer and nano-particles increased. Cross-linkings increase and this helps to more absortion of heat.

→ Formation of Inorganic Layer (760 - 1000 °C) : After burning, only char and inorganic retains. Their reaction helps to create more thermal barrier.



Intumescent Coatings

Char Formation

23°C → 1000°C

Intumescent coated steel	Char Formation	Foam formation	Solidification
Application on steel structure	Binder softs and melts	Fast carbonization and inert gas formation	Oxidation of C to CO or CO_2
Suitable as Exterior: X and Y condition	Polyphosphoric acid releases	Blowing agent decomposition	Mechanical strenght creates by crosslink steps
Suitable as Interior: Y, Z1 and Z2 Condition (Generally water based)	Reaction with OH agent and char forms	Heat Insulation barrier created	Thermal barrier structure via combined with TiO_2

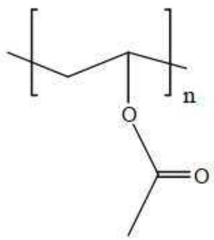
Intumescent Coating Components

Although binder is mentioned less in the literature, its role is undoubtedly important.

- → Eco friendly binder (especially water based) and less carbon foot print is preffered
- → Generally Poly(vinylacetate) types binder

Function of Binder

- → Key component for Minimum Film Forming Temperature (MFFT)
- → Permits foam structure, correct binder type and ratio permits uniform foam structure
- → Good adhesion to surface
- → Important for application conditions Determines application rheology
- → Require optimum viscosity and helpful to get high thickness in one coat application



Poly(vinylacetate)

Binder should have available enough solid content and elasticity that let to creates foam structure

Swelling of Intumescent Coatings

Swelling of the Intumescent product is very important to get good heat insulation and integrity.

→ Good swelling property helps to achieve high thermal performance in the char.

→ Cracks can cause to release inert gases that major swelling component to the out of the char.

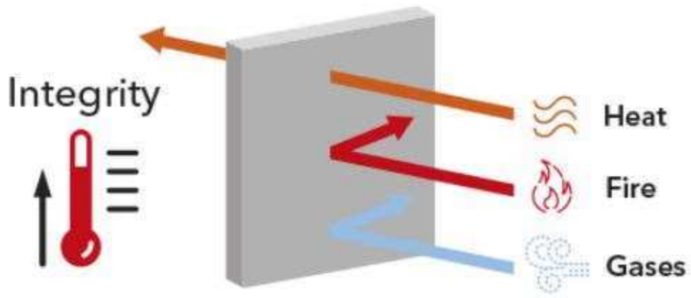
Importance of Char Elasticity

→ Decrease hardness of the char

→ Minimize the cracks and develops the integrity

→ Eliminate the exit of inert gases out of to the char

→ Maximum swelling property



Swelling → Char Elasticity → Minimum Film Forming Temperature (MFFT)

MFFT of the Intumescent product is important to get high char elasticity

MFFT on Fire Resistance

Mfft plays a bit different roles in fire resistance products.

→ Minimize the holes and helps to get uniform dry film surface

→ Reduce the crack observation and requires to good swelling of char

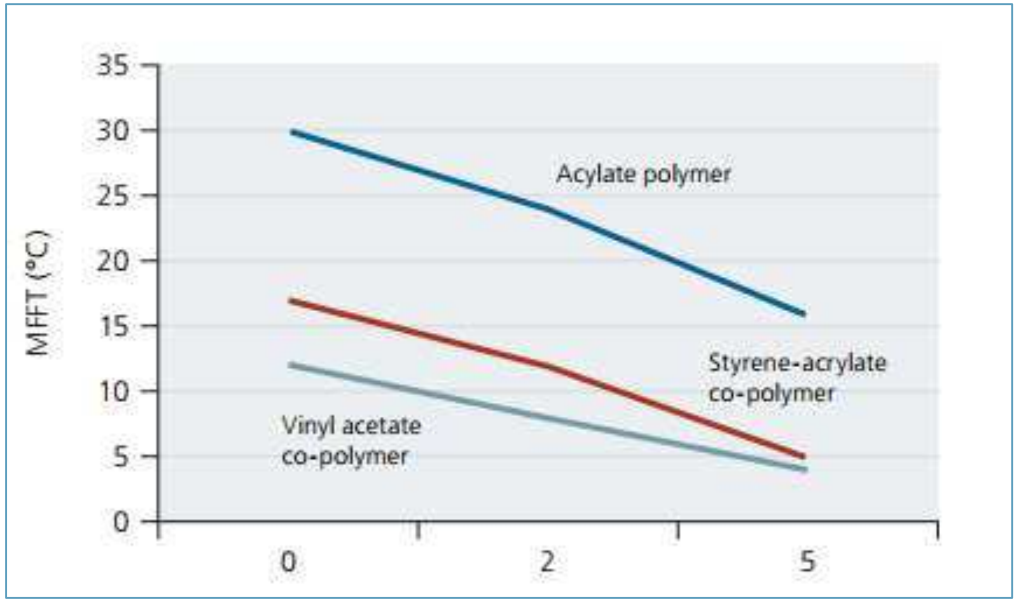
→ Assist to smooth surface on char during the fire

→ Long fire resistance time

Relationship between char elasticity and binder type

It is known that Vinyl acetate co-polymers has lower MFFT values than Acrylate or Stryne acrylate co-polymers. To achieve lower MFFT, correct binder should choose.

- → In this study, the fire resistance performances of products with MFFT values of 15°C, 5°C and 2°C were examined to increase char flexibility
- → Mechanical strenght of char is determined to compare their softness and hardness of the char
- → Swelling volume is calculated
- → Crack observations are examined
- → Uniform foam structure (fluffy, compact or fully compact) char formation is observed



Intumescent Coatings

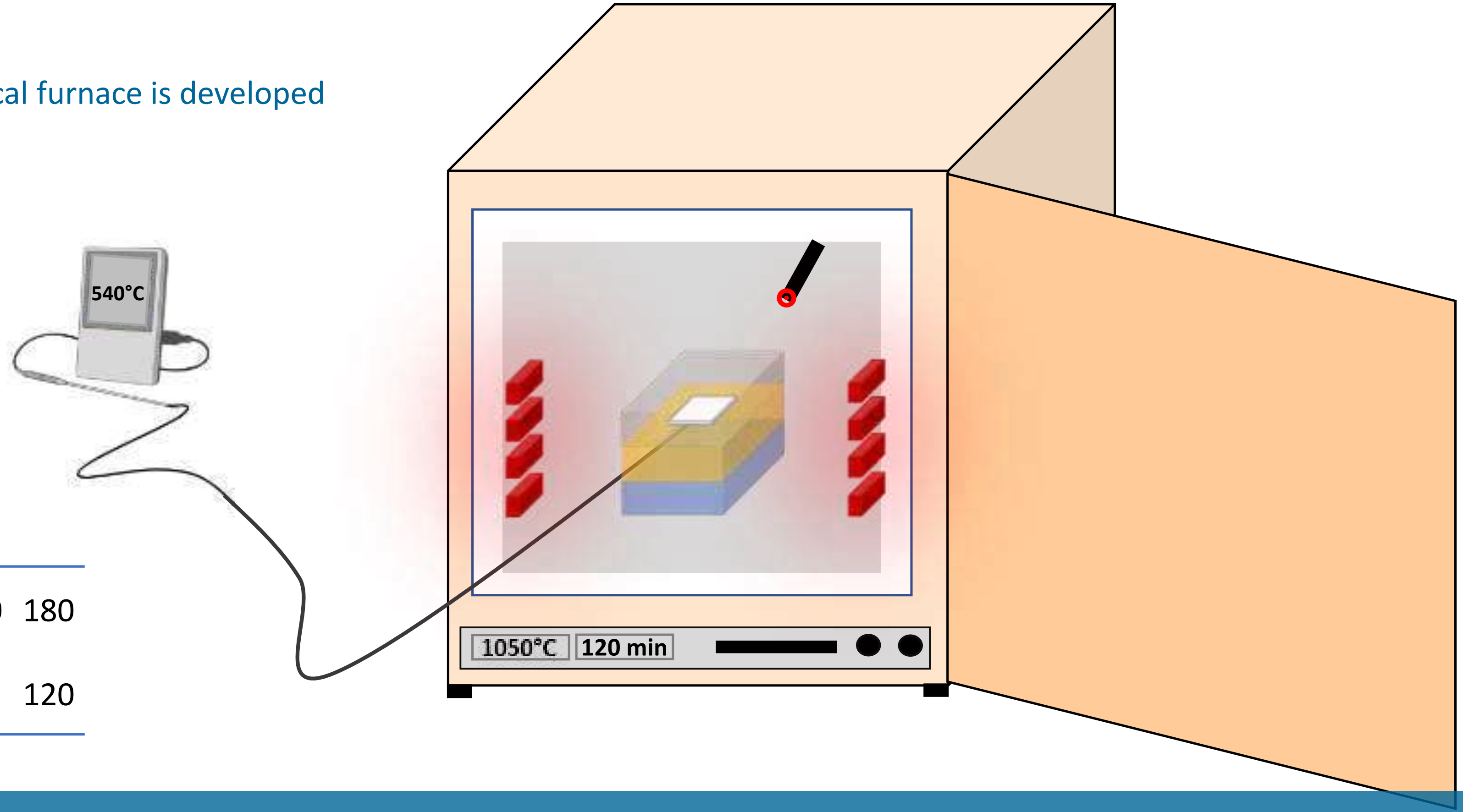
In-House Test Method

In this study, in-house test method that include electrical furnace is developed

→ The study does not represent the industrial furnaces but it can be helpfull guide for next studies. Dont forget that the method can include some deficiencies.

→ This method can be used to compare

Electrical Furnace (min)	15	30	45	60	120	180
Industrial Furnace (min)	10	20	30	40	80	120



180 minutes of fire resistance in Electrical Furnace is equal to 120 minutes fire resistance in Industrial Furnaces.

Intumescent Coating Components

Stable In-House Test Method offers advantages as

→ to compare the correct raw material choosen

→ to determine the performance of competitive product and own formulation

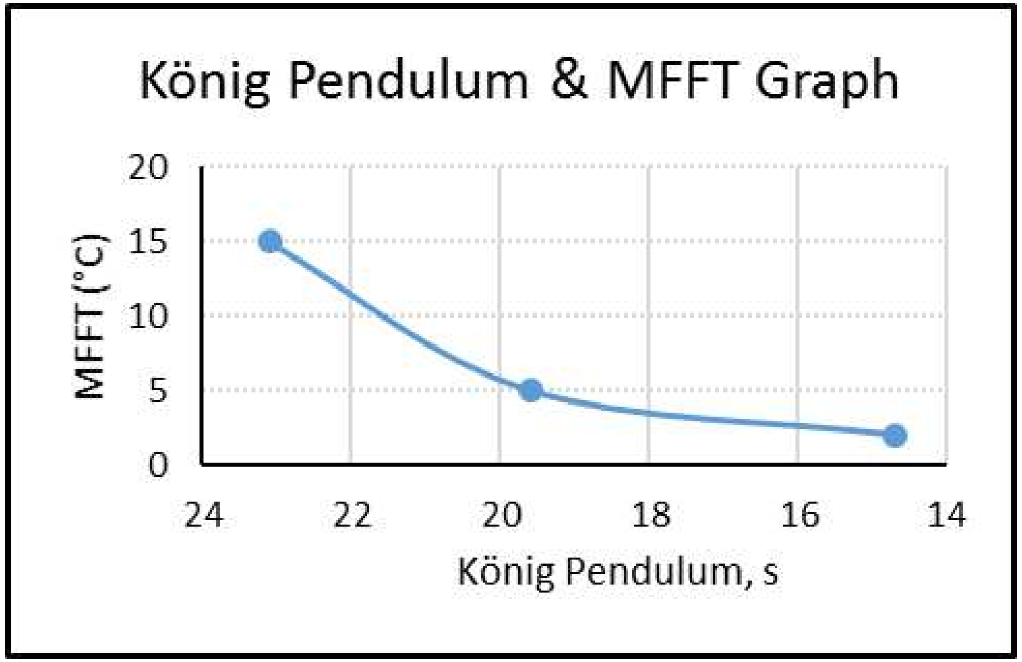
ISO 834 Fire Curve

Tf= 345* log10(8t+1)+20

- Tf is Final Temperature as celcius degree,
- t is time as minute

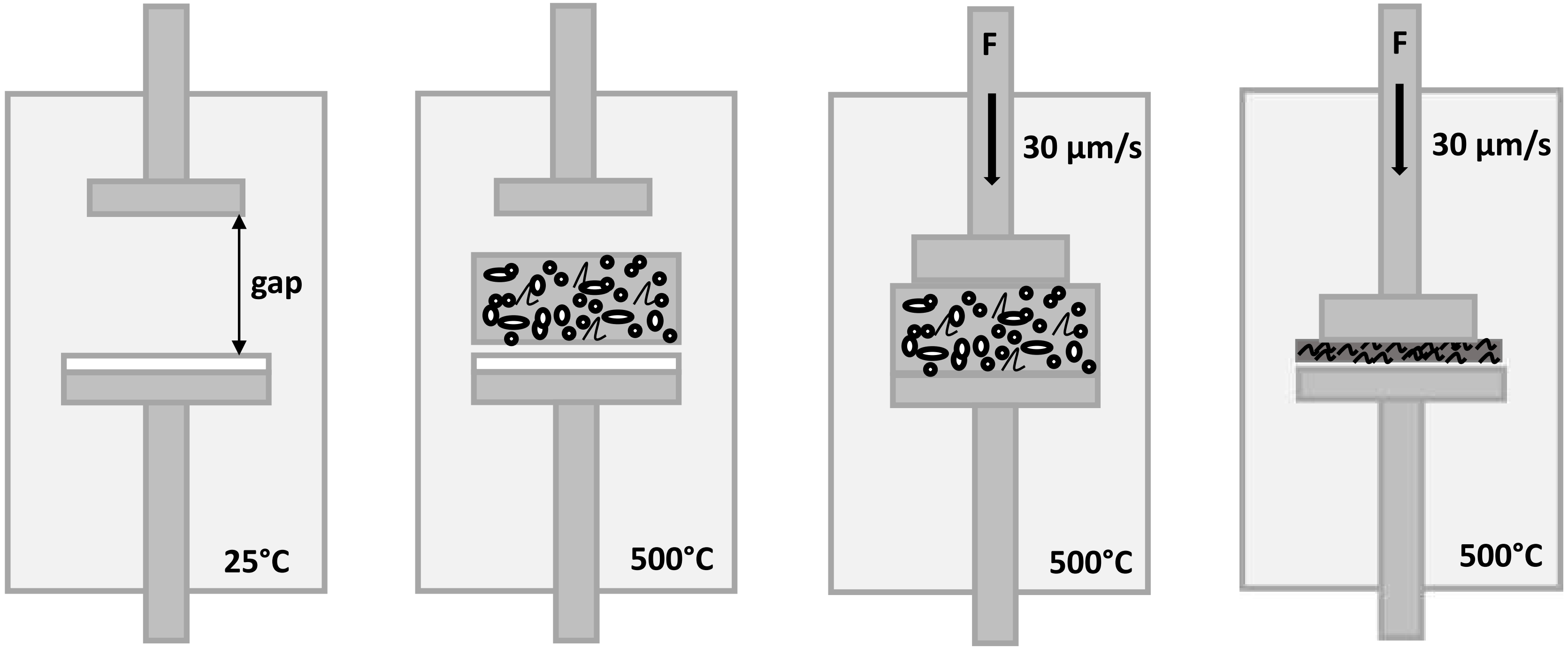
MFFT on Fire Resistance

The measurement of MFFT results are found as 15°C, 5°C and 2°C degree. The samples are applied on steel substrate as ~1000 micron dry film thickness (DFT). König Pendulum value of steel substrates that applied intumescent product are controlled to check same order as MFFT.



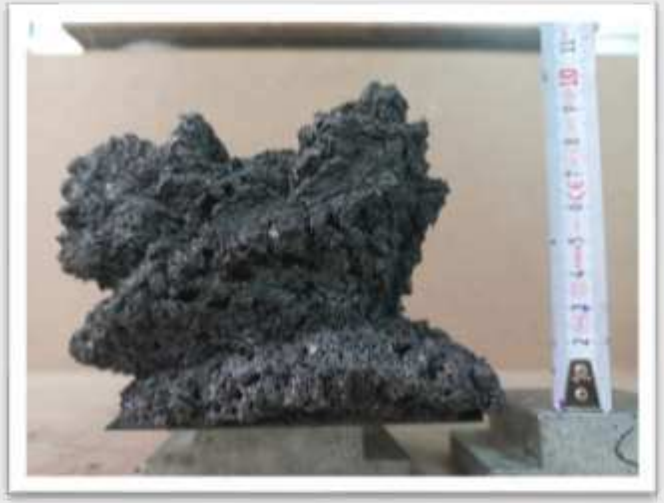
Intumescent Coatings

Swelling and Crush Test In-House Test Method Results*

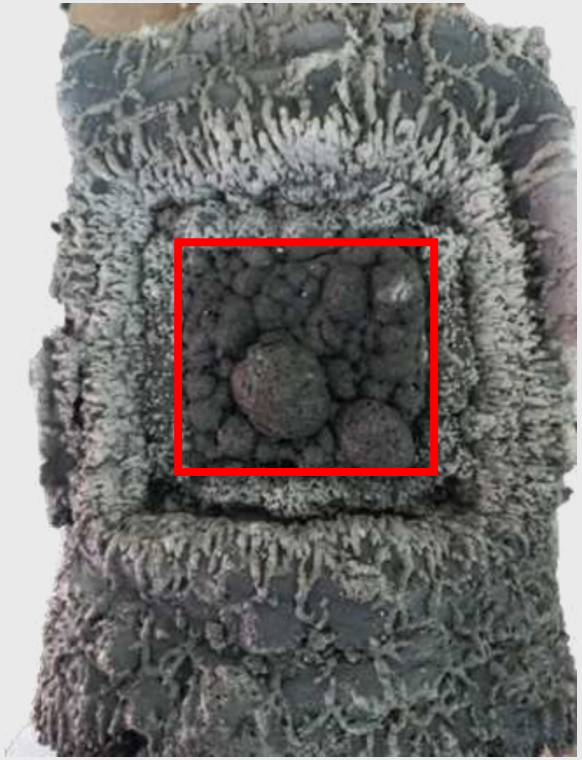


**R.J.Mcnamee, K. Storesund, R.Stolen, The Function of Intumescent Paint for Steel during Different Fire Exposures, SP Sveriges Tekniska Foreskningsinstitut, 2016*

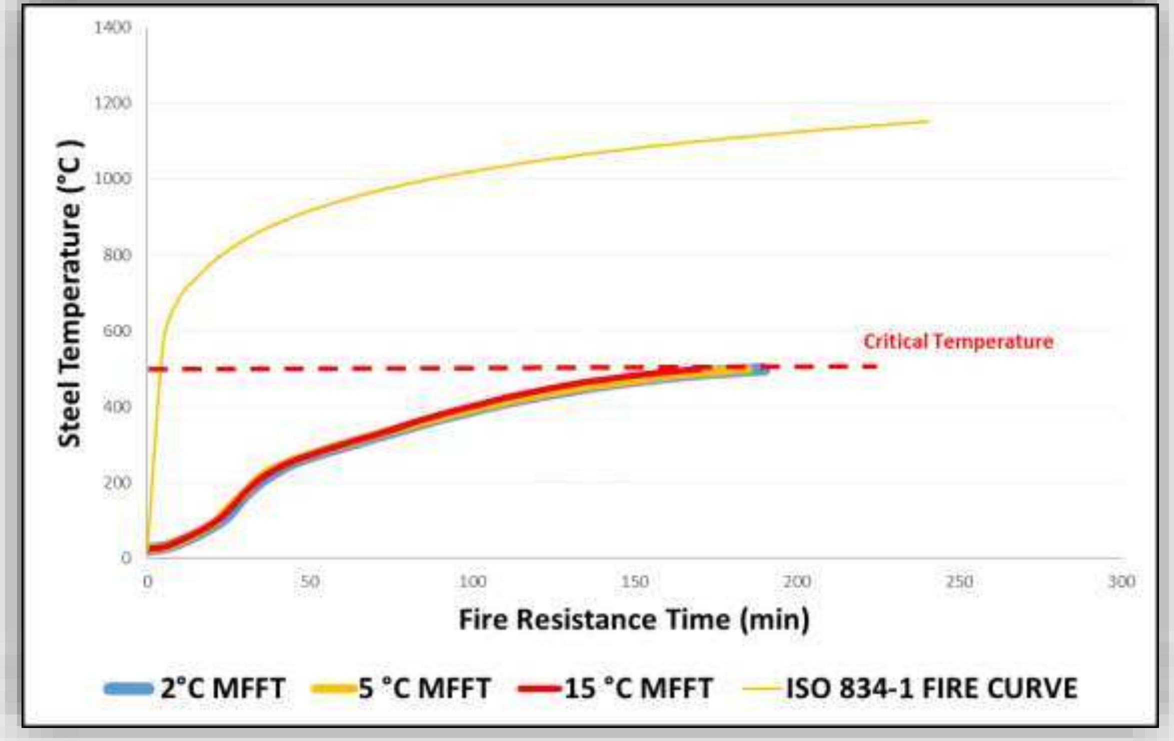
Swelling and Crush Test In-House Test Method Results

PERFORMANCE	15 °C MFFT	5 °C MFFT	2 °C MFFT
SWELLING VISUAL			
DRY FILM THICKNESS (DFT)	1 mm	1 mm	1 mm
THICKNESS OF SWELLING	35 mm	95 mm	105 mm
MECHANICAL STRENGHT	10,6 N	9,1 N	7,6 N

Fire Resistance In-House Test Method Results

PERFORMANCE	15 °C MFFT	5 °C MFFT	2 °C MFFT
CRACK and POROSITY OBSERVATION			
UNIFORM FOAM STRUCTURE	Non-uniform swelling with different bubble diameter	Compact swelling	Fully compact swelling

Results

PERFORMANCE	15 °C MFFT	5 °C MFFT	2 °C MFFT
FIRE RESISTANCE GRAPH			
FIRE RESISTANCE TIME	171 min	187 min	192 min

Summary

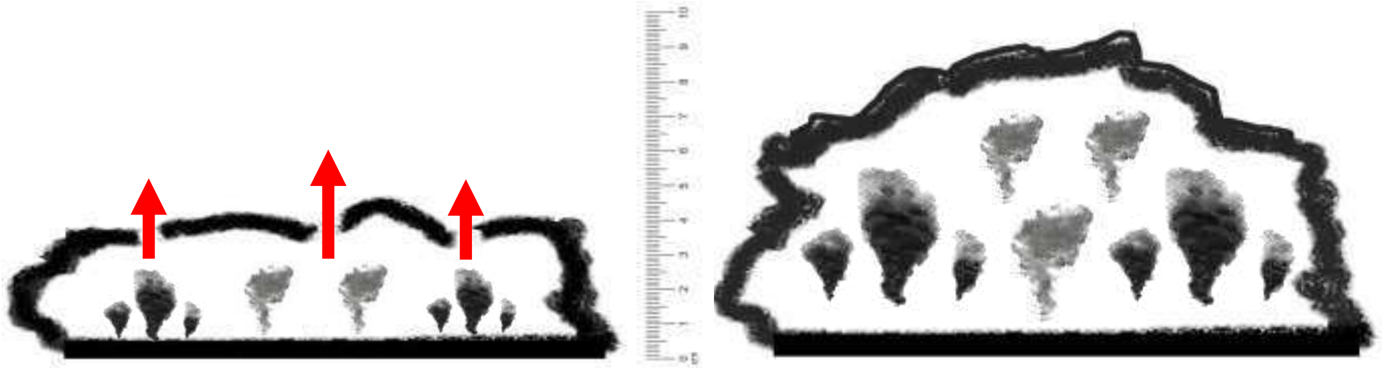
By decreasing MFFT on paint; results are achieved in below;

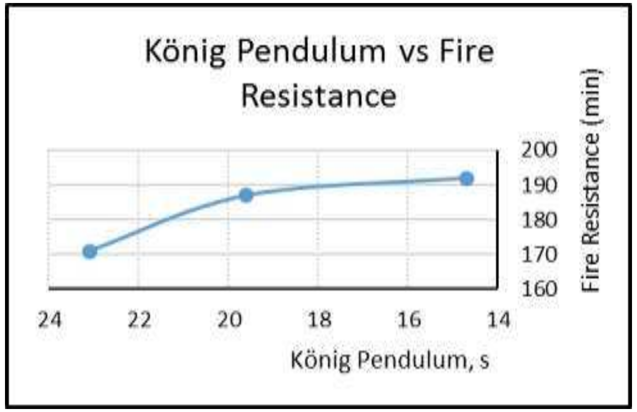
→ Film porosity in char layer decreased at low MFFT values

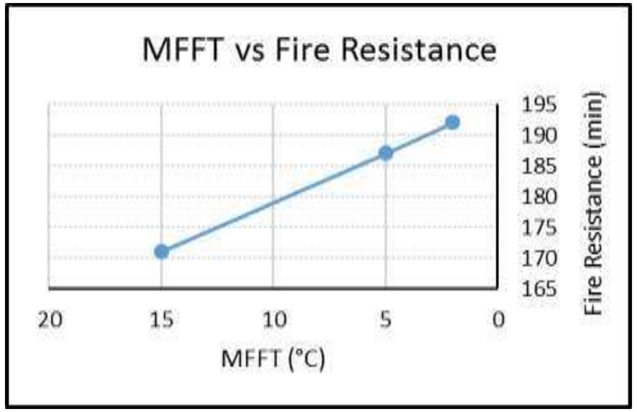
→ Film hardness decreased. As a result of this, cracking tendency decreased.

→ Releases of inert gases avoided and this helped to insulation foam formation.

→ Finally, Fire resistance time is increased.







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Teşekkürler