Spin-Off company of Italian National
Research Council – **CNR**
Materials Division
Via Cocchi 7, 56121 Pisa – Italy

University of Applied Science and Arts of
Southern Switzerland – **SUPSI**
Institute for Mechanical Engineering and
Materials Technology – **MEMTi**
Galleria 2, CH-6928 Manno – Switzerland

Mini-SBI for testing of fire retardant properties of HFFR compounds for cables

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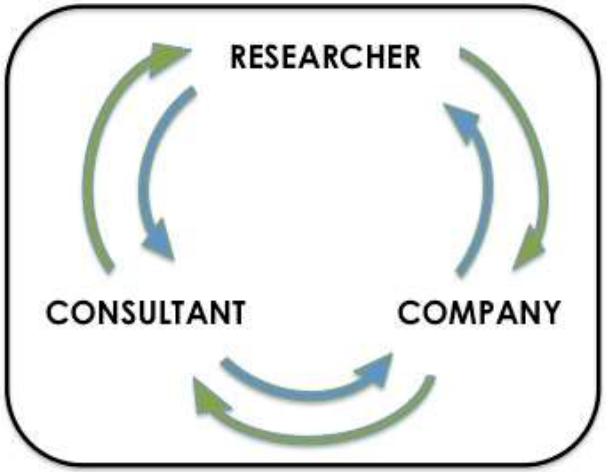

Mission

Industrial and environmental development of know-how applications on chemical and physical properties of materials and on specific instruments.

Technical consulting about design, industrialization and marketing of raw materials and compounds with high performance, instrumental analytical technologies for monitoring and modification of processes.

Specialized services of Applicative Research and Technological Development for companies working in the material industrial sector.

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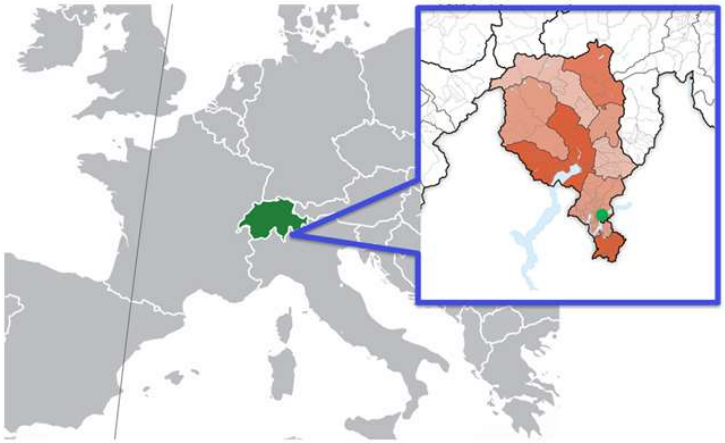


Institute for Mechanical Engineering and Materials Technology

	Mechanical Engineering	Hybrid Materials	Thermofluid Dynamics	Therapeutic Technologies	Bio-Environmental Technologies
Research topics	▪Structural simulations (FEM) ▪Plastic injection moulding ▪Metal stamping	▪Ceramic foams ▪Composite materials ▪ Polymeric materials ▪ Surface chemistry	▪ Simulations of gas/liquid flows ▪Thermodynamics	▪Pharmaceutical technologies ▪Medical systems ▪Computational modeling ▪Quality assurance & regulatory issues	▪Waste water treatment ▪Bio-mass techn. ▪Material recovery

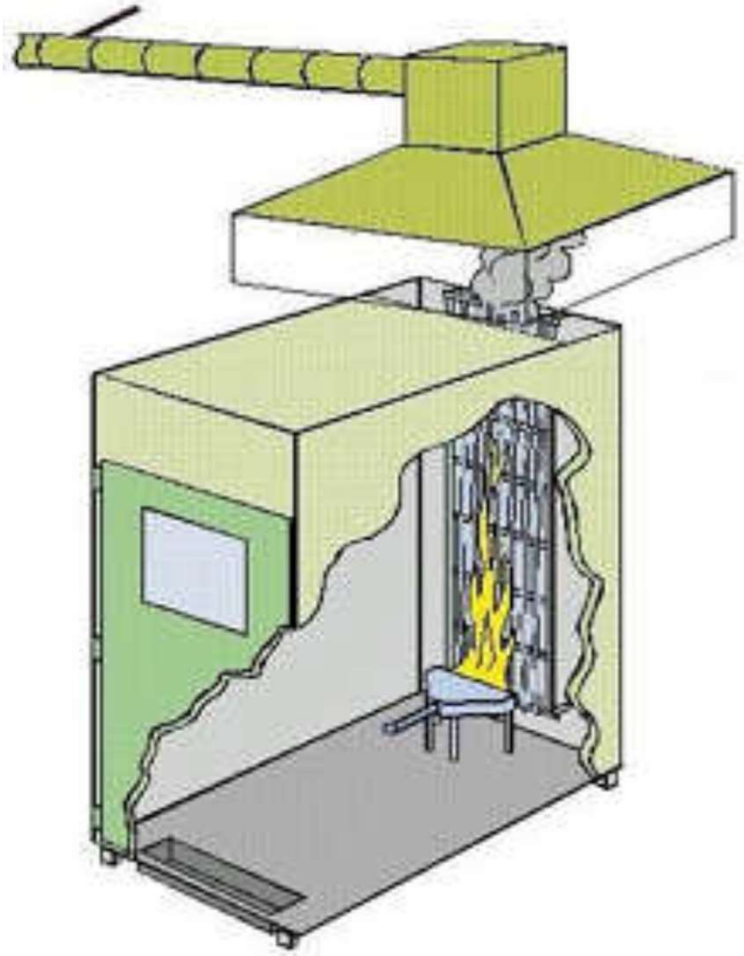
Standards for FR products

Construction Product Regulation (CPR) EU 305/2011

Harmonization of fire properties for contruction products in the European Union.

Cables and lines are classified as construction products.
All the past test methods are summarised in the large-scale test EN 50399:

- Type of specimen: cables and lines
- Sample orientation: VERTICAL (cables mounted on a ladder)
- Ignition source: gas burner at the bottom of the series of cables
- Flame application: 20 min
- Results: flame spread, parameters related to heat release, smoke production, acidity of gases, flaming droplet



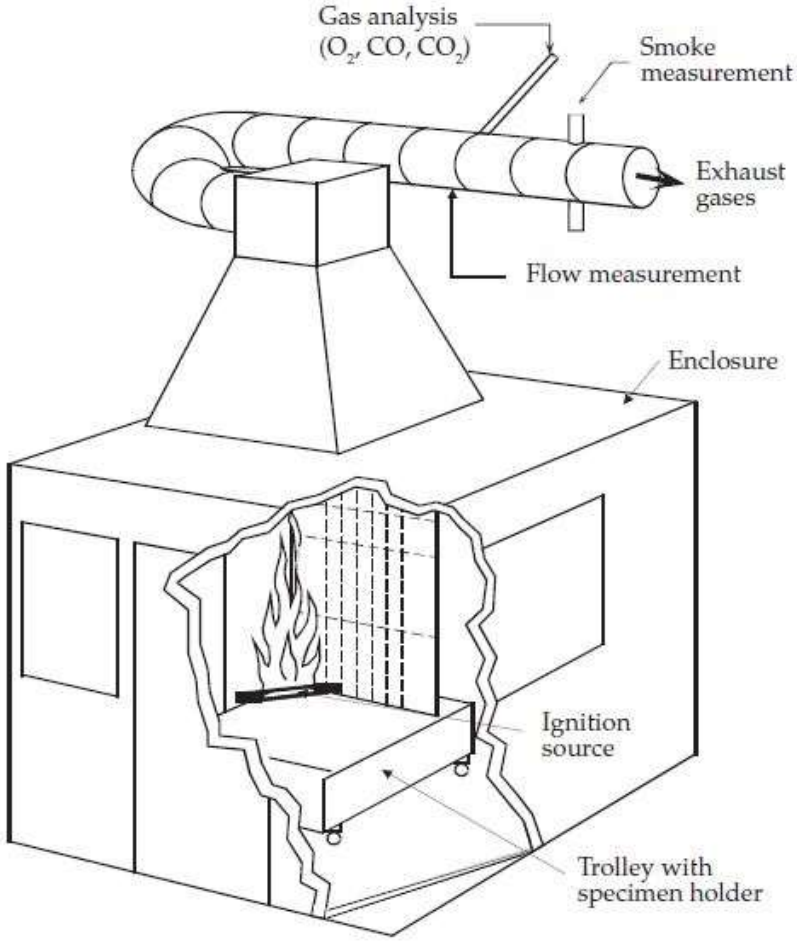
Girardin et al, Journal of Fire Sciences, 2016, 34(3) 240–264
Gallo et al, Fire and Materials, 2016,DOI: 10.1002/fam.2417

Standards for FR products

Single Burning Item (SBI)

SBI is a large scale method for evaluating the burning behavior of construction materials, typically for roofing, flooring or panels application (EN 13823)

- Type of specimen: big panels/sheets
- Sample orientation: VERTICAL (sheets mounted on two sides of 90° corner)
- Ignition source: gas burner at the basis of the specimen corner
- Flame application: 20 min
- Results: flame spread, parameters related to heat release, smoke production, flaming droplet



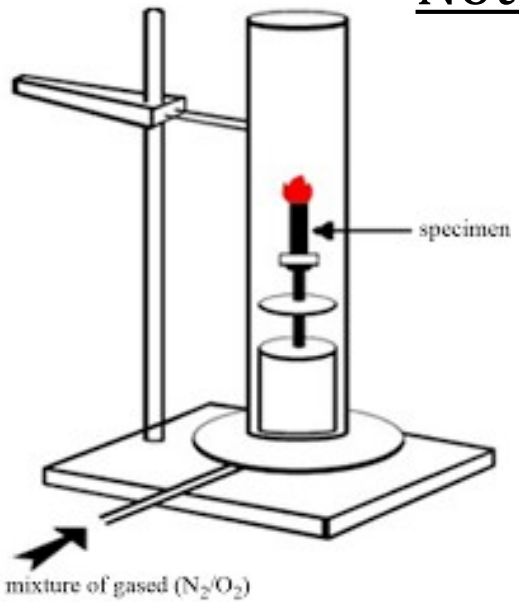
van Mierlo et al, HERON, 2005, 50 (4) 191–207

Laboratory tests for FR materials

Not calorimetric

LOI (ASTM D2863)

- sample orientation: VERTICAL (flame application at the top of the specimen)
- type of specimen: small stick 100x6x3 mm
- variation of oxigen-nitrogen ratio
- results: minimum oxigen concentration



Vertical burning test (UL94V, DIN 4102…)

- sample orientation: VERTICAL (flame application at the bottom of the specimen)
- type of specimen: small sheets of different size depending on the standard type
- results: evaluation of stop burning materials , burning rate, flame spread…

Laboratory tests for FR materials

Calorimetric

Cone Calorimeter (ISO 5660)

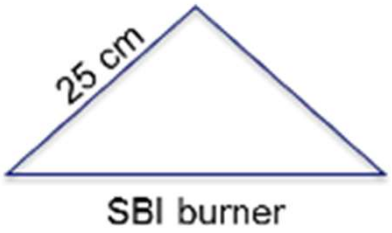
- sample orientation: HORIZONTAL (heat irradiation)
- type of specimen: 100x100 mm tile (3-5mm thick)
- self ignition on the surface by irradiation + spark
- results: time to ignition and parameters related to heat release and smoke production

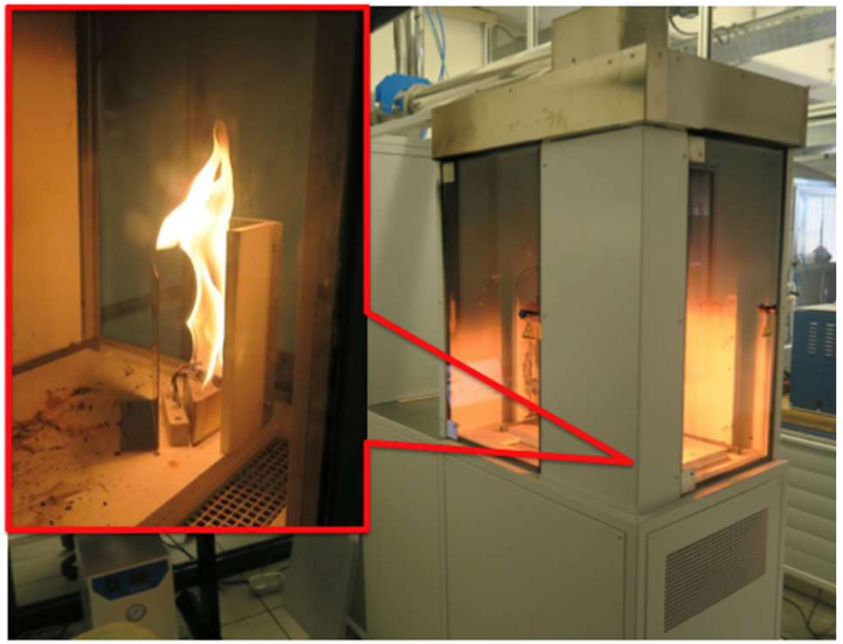
For evaluation of FR properties of materials in order to be used for products can pass large scale tests, the common laboratory tests reported are not enough "predictive":

No correlation between laboratory and large scale tests.

Laboratory tests for FR materials

Mini–SBI: a downscaled of SBI method





Standard SBI → **Mini - SBI**

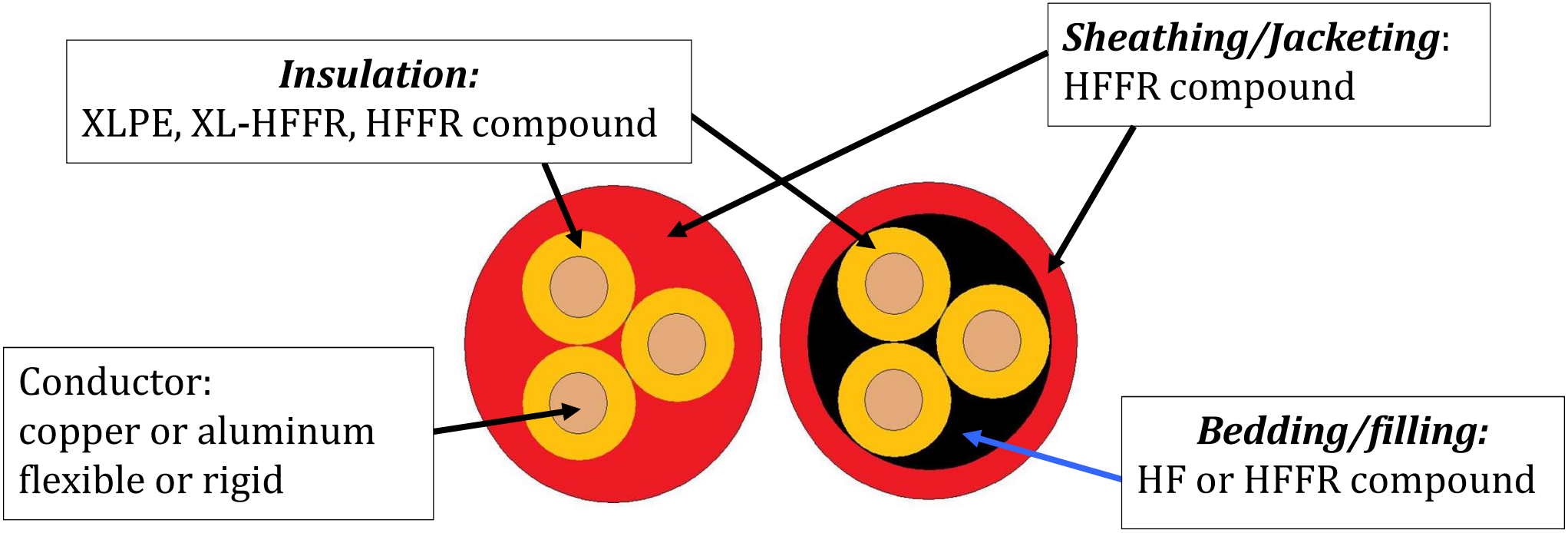
	Specimen surface [m^2]	Burner Dimensions [cm^2]	Power of burner [Kw]
SBI	2.25	312.5	30
MiniSBI	0.375	24.5	2 - 5

Mini-SBI tests on cable materials

Application of Mini-SBI method for analysing the FR properties of materials used for cables production because:

- Vertical orientation of the specimen
- Flame spread, heat release and smoke production analysis
- Flaming droplet evaluation

Cable materials for tests:



Formulations

Product	Trade name	Sheating	Insulation	Bedding
		phr	%	%
EVA28 – MFI 3	Elvax 265	40		
ULDPE – MFI 1,2	Lucene LC180	40	25,5	
mLLDPE – MFI 3,5	Exceed 3518	10	6	
LLDPE - MFI20	SABIC M200024			19
LLDPE-g-MAH	Compoline CO/LL	10	3	2
Stabilizer/Antioxidant	Silmastab AE1527	1,5	0,5	
Hydrofobic agent	Silmastab AX2244	1,5	0,5	
Silicon processing aid	Silmaprocess AL1142A	3	1	1
EVA Wax	Viscowax 353			2
Fillers		160	63,5	76
Total		*264,5*	*100*	*100*

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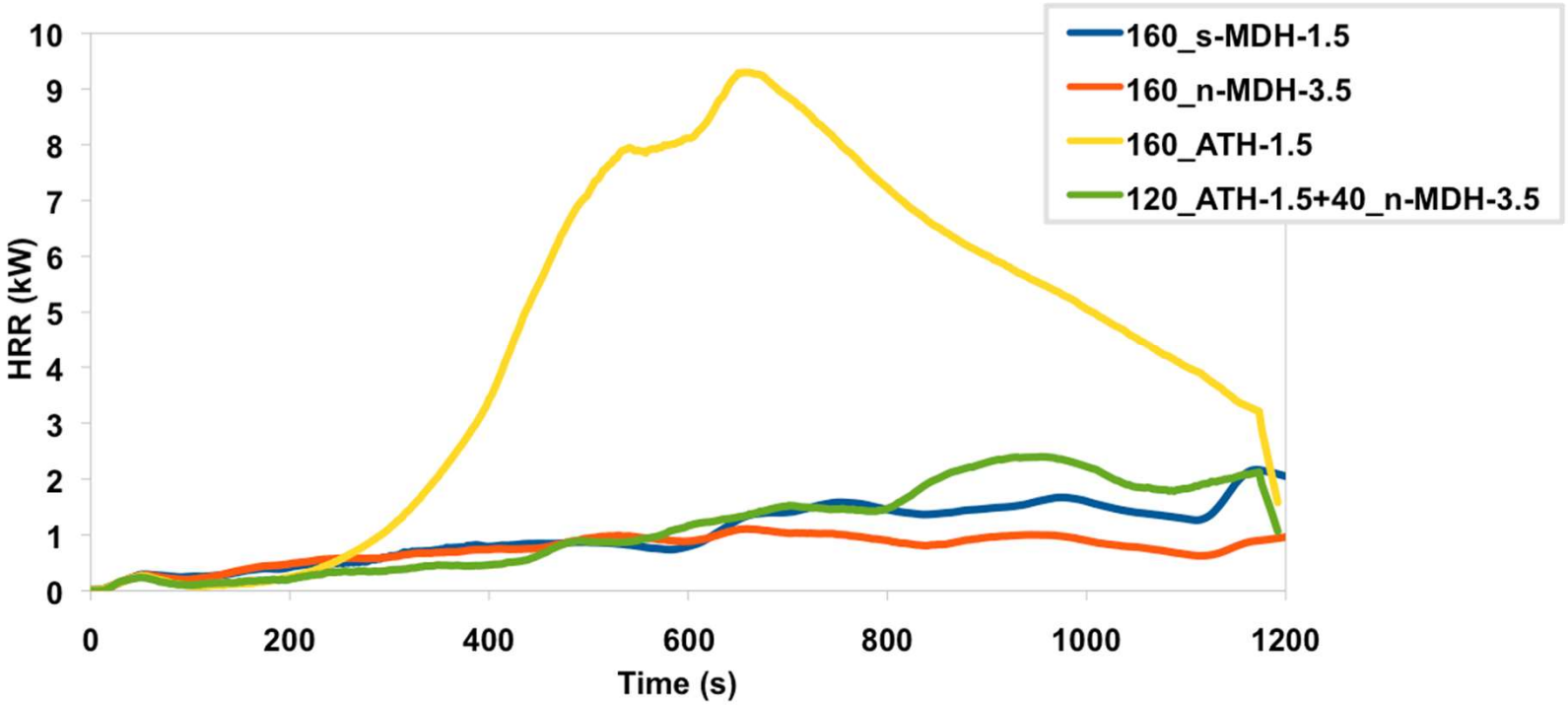
Fillers for different applications

Fillers	Trade name	Sheating	Insulation	Bedding
Synthetic aluminium hydroxide d50=1.5µ (**ATH-1.5**)	Apyral 40CD	✓	✓	
Synthetic aluminium hydroxide d50=15µ (**ATH-20**)	Alolt 8			✓
Synthetic magnesium hydroxide d50=1.5µ (**s-MDH-1.5**)	Magnifin H5	✓	✓	
Brucite d50=3.5µ (**n-MDH-3.5**)	Ecopiren 3.5	✓	✓	
Brucite d50=10µ (**n-MDH-10**)	Ecopiren 10			✓
Stearic acid coated brucite d50=3.5µ (**n-MDH-3.5C**)	Ecopiren 3.5C	✓	✓	
Stearic acid coated brucite d50=10µ (**n-MDH-10C**)	Ecopiren 10C			✓
Silane coated brucite d50=3.5µ (**n-MDH-3.5NP**)	Ecopiren 3.5NP	✓		
Böhmite d50=2.5µ (**Böhmite-2.5**)	Aluprem TB dry	✓		
Calcium borate (**CaB**)	Portaflame CA13	✓		

Sheating compounds

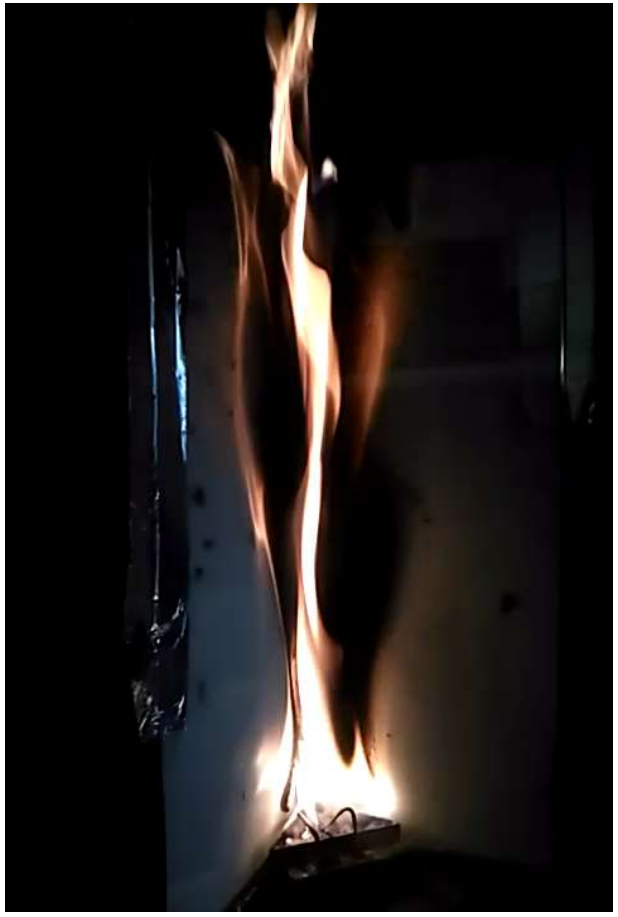
Aluminium and magnesium hydroxides



Fillers	HRR peak (kW)	FIGRA (W/s)	THR (MJ)	SPR peak (m^2/s)	SMOGRA (m^2/s^2)	TSP (m^2)
160_s-MDH-1.5	2,16	2,32	1,75	0,016	0,022	3,51
160_n-MDH-3.5	1,11	2,54	0,89	0,015	0,023	3,66
160_ATH-1.5	9,31	14,8	5,30	0,047	0,067	24,3
120_ATH-1.5+40_n-MDH-3.5	2,40	2,57	1,34	0,016	0,020	5,73

Burning behaviour

*<u>Not-dripping compound</u>: **low** values of burning parameter*



Flame evolution

Burning residue

Burning behaviour

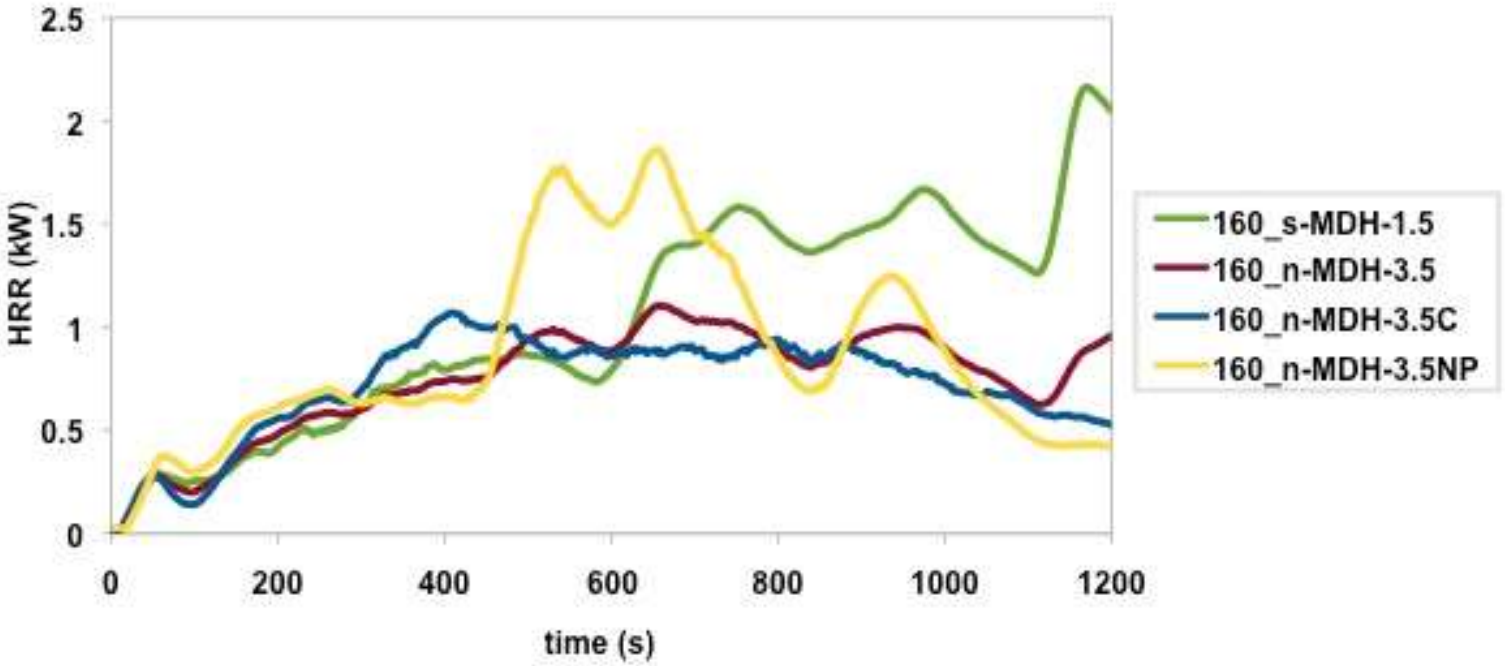
*<u>Dripping compound</u>: **high** values of burning parameter*

Flame evolution

Burning residue

Sheating compounds

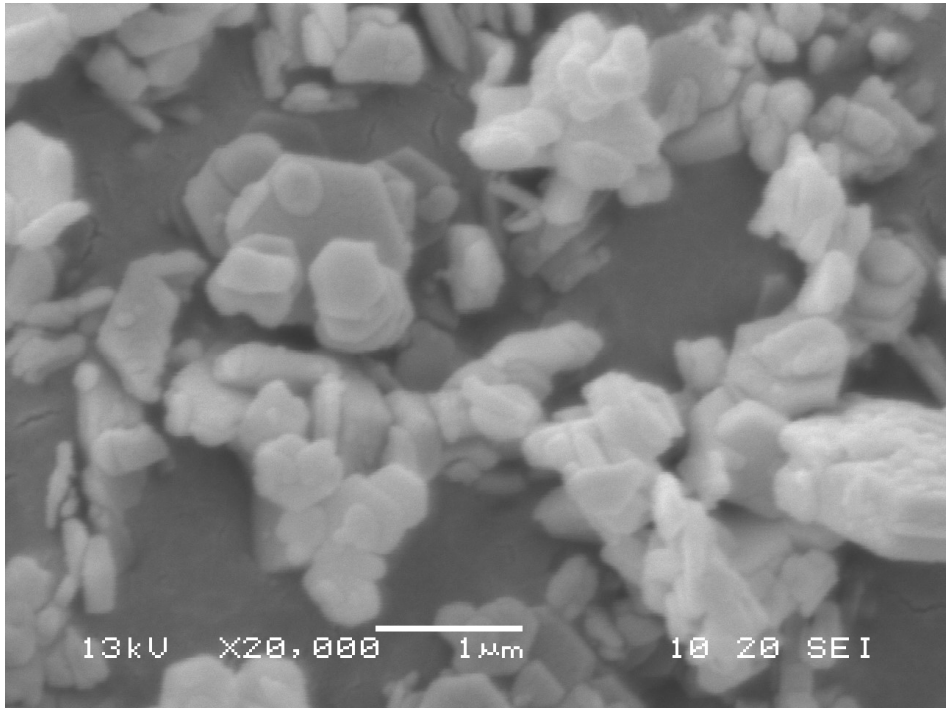
$Mg(OH)_2$: synthetic vs natural



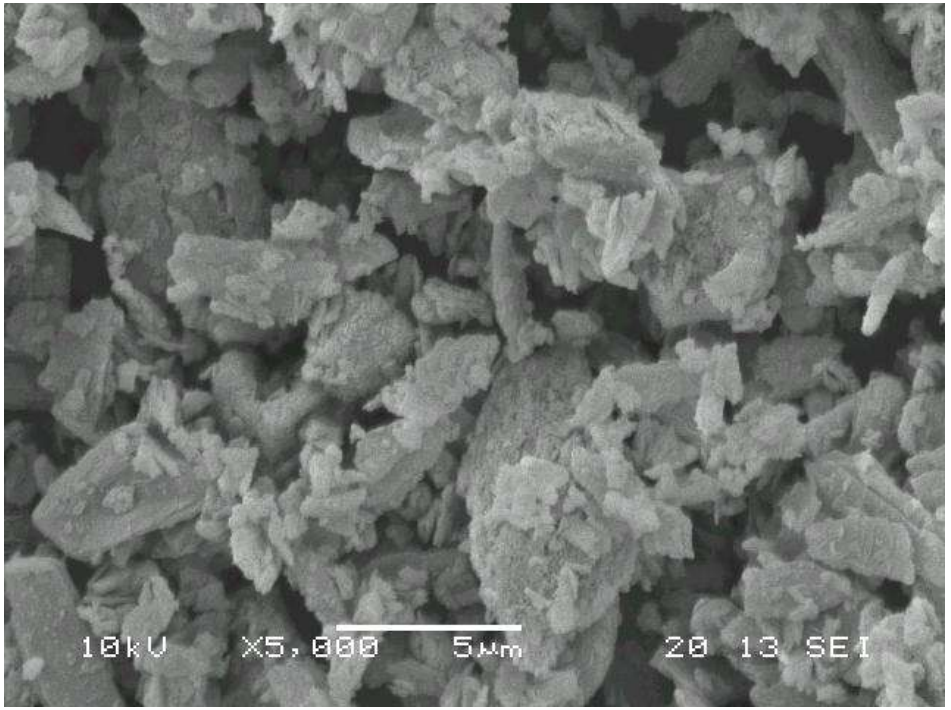
Fillers	HRR peak (kW)	FIGRA (W/s)	THR (MJ)	SPR peak (m^2/s)	SMOGRA (m^2/s^2)	TSP (m^2)
160_s-MDH-1.5	2,16	2,32	1,75	0,016	0,022	3,51
160_n-MDH-3.5	1,11	2,54	0,89	0,015	0,023	3,66
160_n-MDH-3.5C	1,07	2,94	0,87	0,016	0,028	4,43
160_n-MDH-3.5NP	1,86	3,37	1,04	0,007	0,006	0,99

Sheating compounds

$Mg(OH)_2$: synthetic vs natural



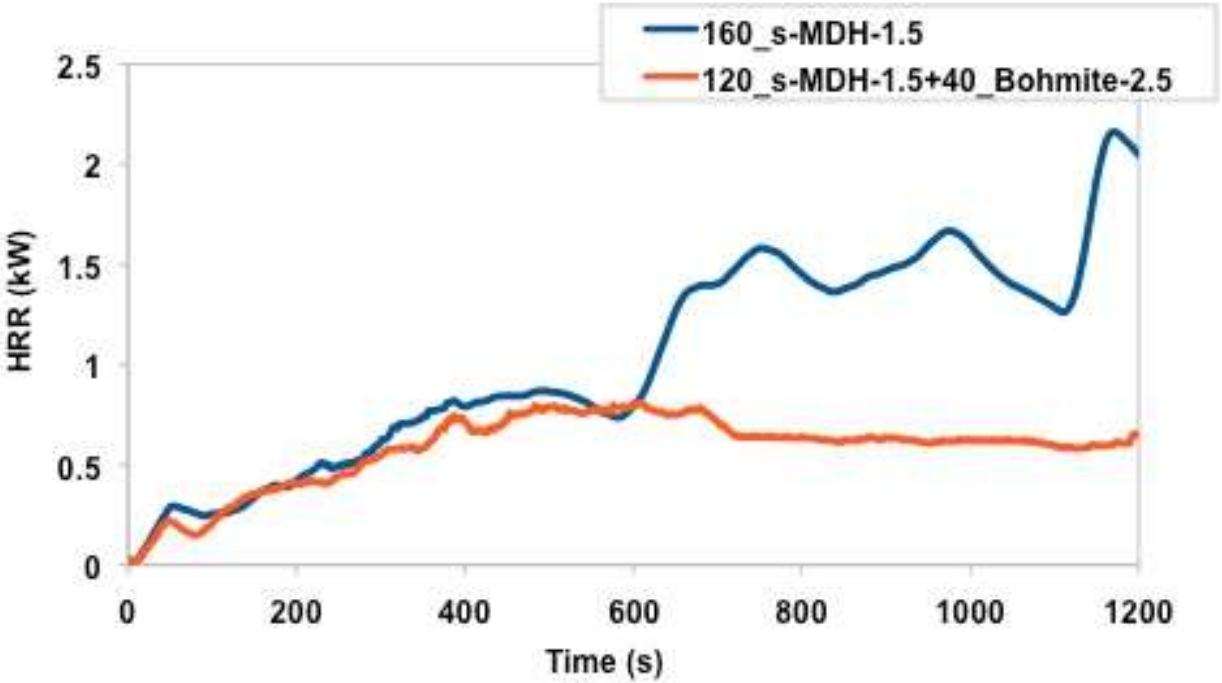
Precipitated and crystallized MDH

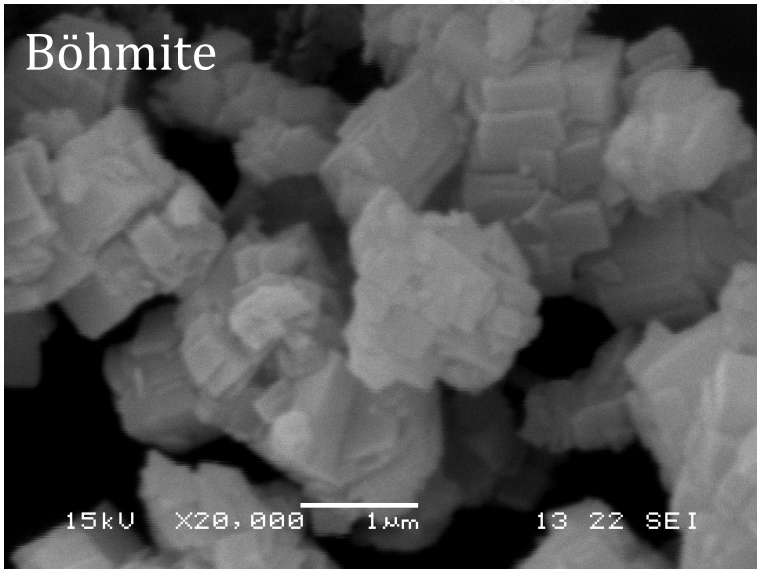


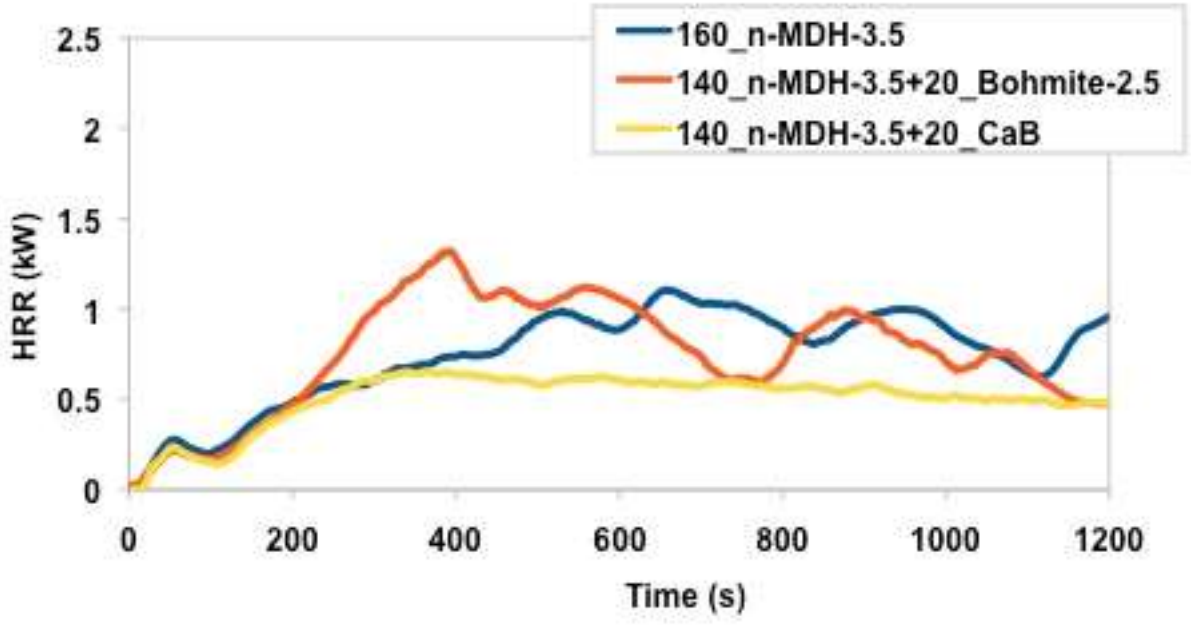
Natural MDH (brucite)

Sheating compounds

Synergist fillers

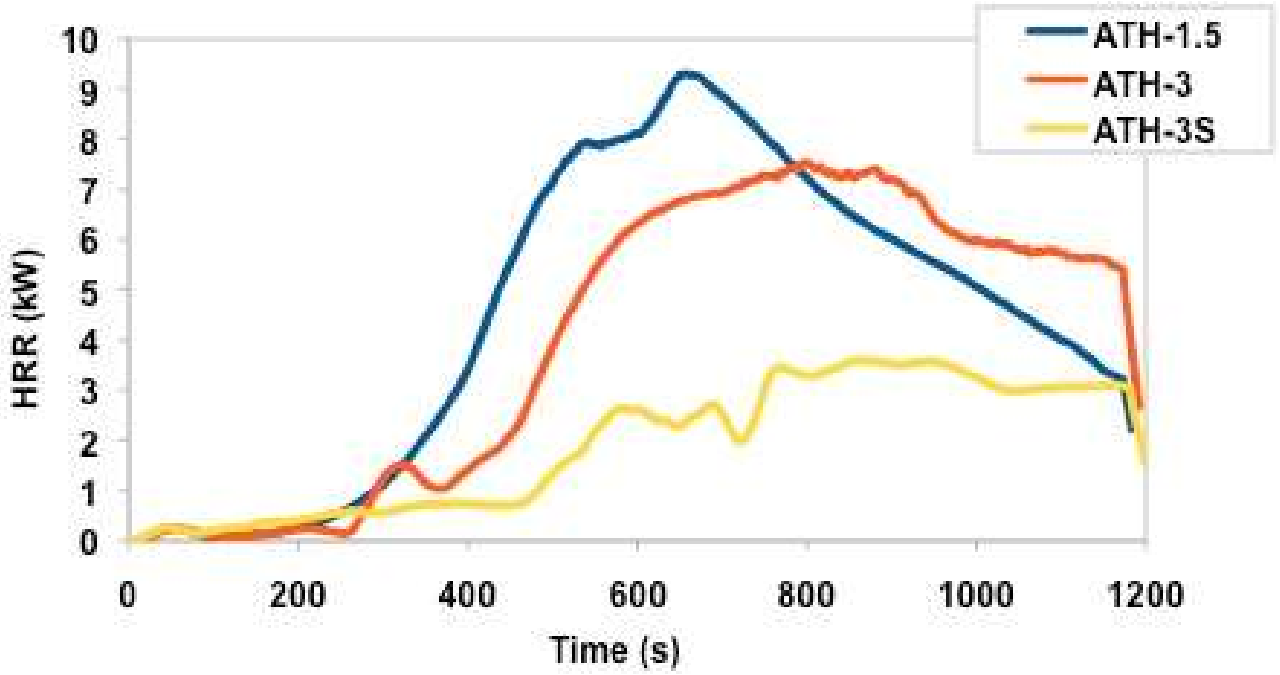






Sheating compounds

Different aluminium hydroxides

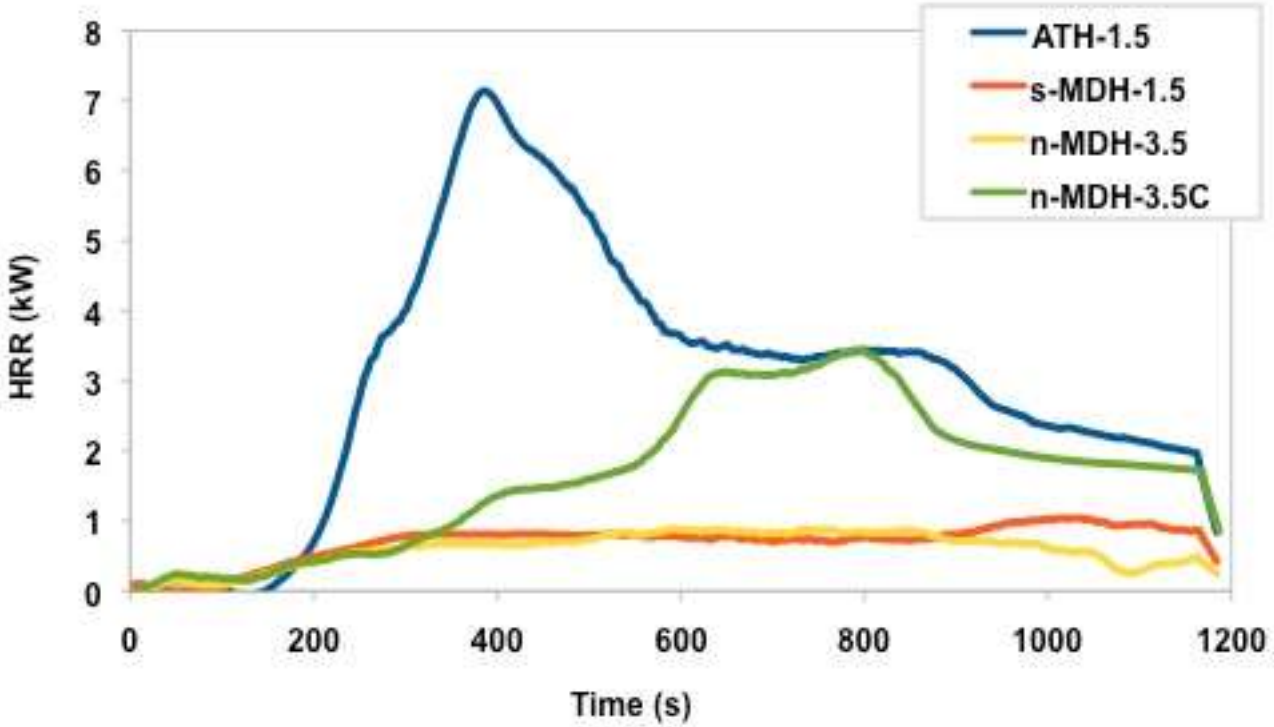


Fillers
Synthetic aluminium hydroxide d50=1.5µ (**ATH-1.5**)
Synthetic aluminium hydroxide d50=3µ (**ATH-3**)
Silane coated synthetic aluminium hydroxide d50=3µ (**ATH-3S**)

Fillers	HRR peak (kW)	FIGRA (W/s)	THR (MJ)	SPR peak (m^2/s)	SMOGRA (m^2/s^2)	TSP (m^2)
ATH-1.5	9,31	14,8	5,30	0,047	0,067	24,3
ATH-3	7,54	10,6	4,8	0,037	0,069	18,3
ATH-3S	3,6	4,54	2,29	0,026	0,033	10,1

Insulation compounds

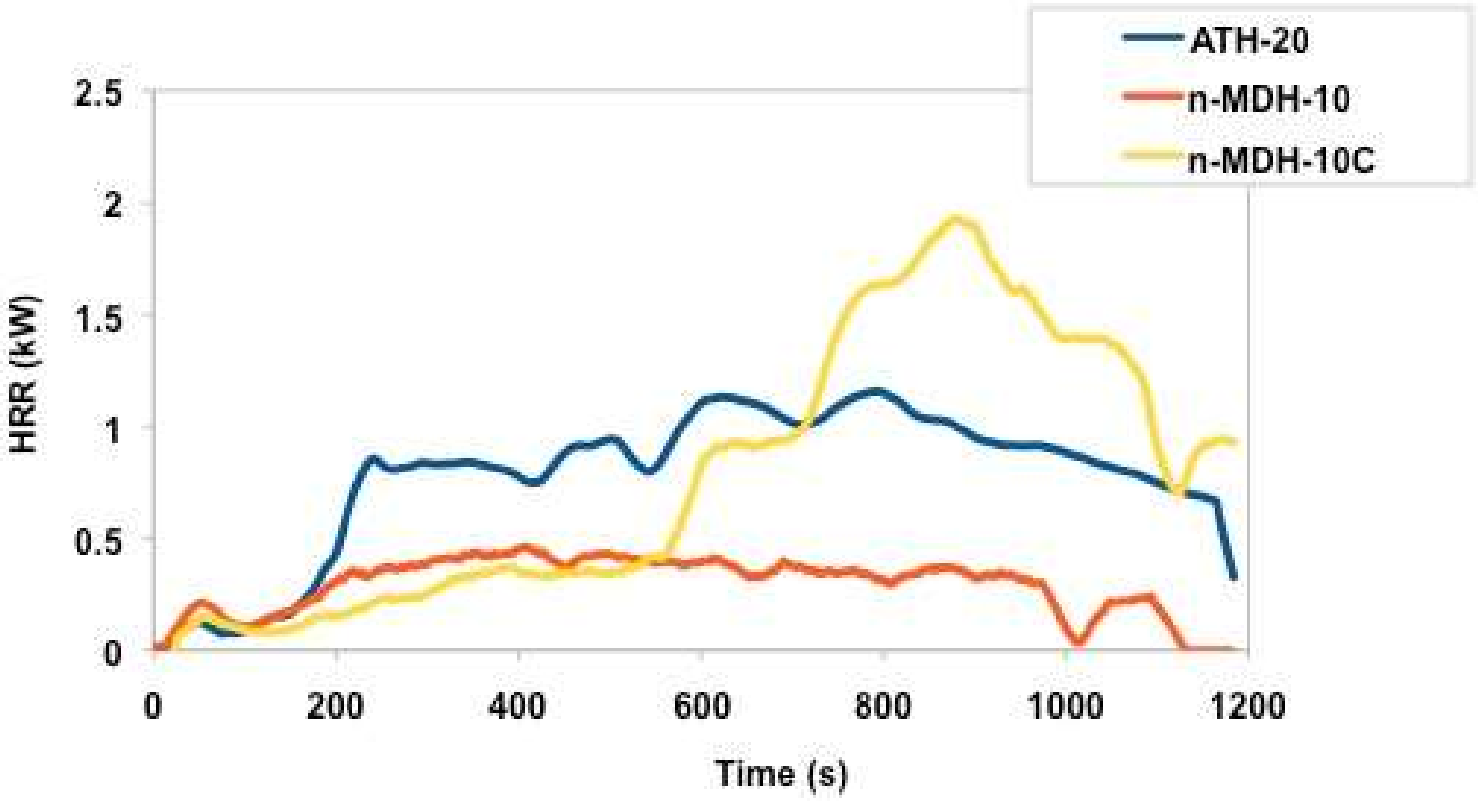
Aluminium and magnesium hydroxides



Fillers	HRR peak (kW)	FIGRA (W/s)	THR (MJ)	SPR peak (m^2/s)	SMOGRA (m^2/s^2)	TSP (m^2)
ATH-1.5	7,14	18,7	3,59	0,044	0,082	18,80
s-MDH-1.5	1,04	2,63	0,82	nd	nd	nd
n-MDH-3.5	0,89	2,25	0,71	0,003	0,011	1,70
n-MDH-3.5C	3,34	4,86	1,96	0,022	0,019	6,27

Bedding compounds

Coarse fillers



Fillers	HRR peak (kW)	FIGRA (W/s)	THR (MJ)	SPR peak (m^2/s)	SMOGRA (m^2/s^2)	TSP (m^2)
ATH-20	1,16	3,57	0,92	0,013	0,044	5,65
n-MDH-10	0,46	1,62	0,35	0,004	0,019	3,63
n-MDH-10C	1,93	2,20	0,94	0,010	0,012	3,31

Results of mini SBI

- The best behaviour in fire test (=the lowest values of FIGRA and SMOGRA) have been reached in materials containing MDH.
- Main reason of the better performances of MDH containing materials is the NOT dripping and NOT collapsing behaviour. It's enough to have ATH:MDH in the ratio 3:1 to get already higher level of performances.
- This is in agree with all information we got from the market, where all cables sheathed with MDH containing compounds gave superior performances in EN 50399.
- Fine precipitated MDH and fine milled natural brucite perform in mini SBI in a comparable way, as no relevant differences have been shown.
- Stearic acid and silans coated fillers showed a bit difference performance in comparison to uncoated versions.

Applications of mini SBI

- Mini SBI technic offers a new laboratory scale way to compare behaviour of halogen free flame retardant polymeric compounds with prospective to be used in EN 50399 fire test for CPR classification.

- Mini CPR does NOT replace the EN 50399 test on cables, but it gives in a fast way preliminary and comparative screening on HFFR compounds about behaviour in order to:

- - compare different raw materials (fillers, lubricants, coupling agents,….) in the existing recipes
- - improve recipes for better fire behaviour in EN 50399 by introducing new ingredients and finding synergisms
- - provide data to better design new cables

- Further improvement of mini SBI technical are in progress, especially to reduce the overestimation of dripping in cable applications