Near Surface Mounted Reinforcement

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ie-net
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RC beams strengthened with NSM reinforcement: Ambient and Fire behaviour

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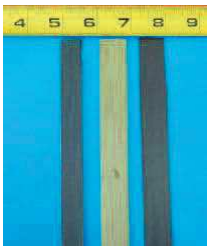
Near Surface Mounted (NSM) FRP

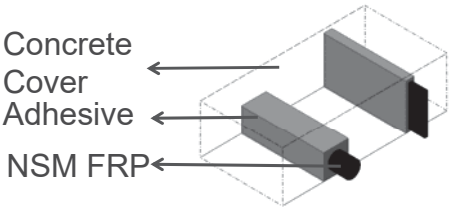
GFRP rods



CFRP/GFRP strip

CFRP rods

NSM FRP: Applications



High bond characteristics
Higher utilization FRP bars
Improved resistance to fire

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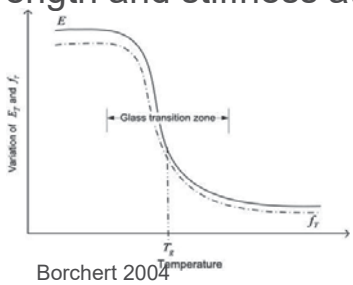
FRP Properties at High Temperatures

- FRP fibers generally exhibit a good fire resistance
- Epoxy lose strength and stiffness at temperature close to T_g



Borchert 2004

Tg: Glass transition temperature is commonly taken as the performance limit for the FRP strengthened members
- Typically 60 – 80°C -

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FRP and Fire: Concerns

Fire is recognized as a critical research need for FRP:

- a primary factor preventing widespread application on FRPs in buildings

Potential concerns during fire:

- Loss of strength and stiffness
- Loss of interaction (bond) adhesive/FRP/concrete
- Smoke generation and flame spread

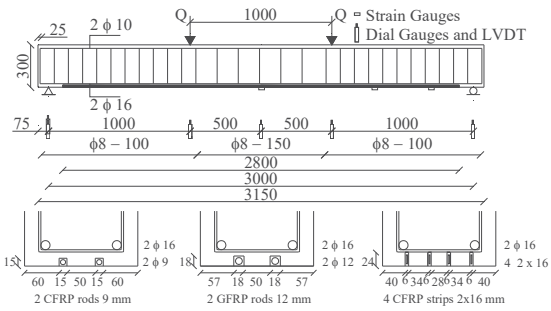
Problem Statement:

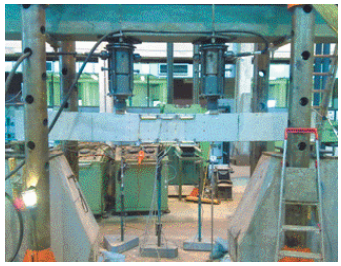
Concrete structures strengthened with FRPs perform weak under fire conditions : thermal protection is required

Research Objectives

- Evaluate the performance of NSM FRP strengthened and insulated members at ambient temperature and under fire exposure
- Develop practical methods for protecting FRP strengthening system during fire exposure
- Evaluate the performance of different insulation materials type in terms of efficiency and in terms of practical application
- Investigate the residual capacity of the fire tested beams

Sample Specimens





Test Matrix

Beam	FRP	D_f [mm]	f_f [Mpa]	E_f [Gpa]	Epoxy resin	T_g [°C]	f_c [MPa]	Age at testing [days]
B0	-	-			-		48.0	111
B1	Combar GFRP	12.0	1350	60	Sikadur 30	62	50.0	109
B2	Aslan 200 CFRP	9.0	1900	126	Fortresin	65	48.0	111
B3	Aslan 500 CFRP	2x16	2068	124	Fortresin	65	49.0	105

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Installations FRP NSM Bars/Strips

1. Cutting Grooves and Cleaning

2. Filling with adhesive

3. Insert bar/strip

4. Final levelling

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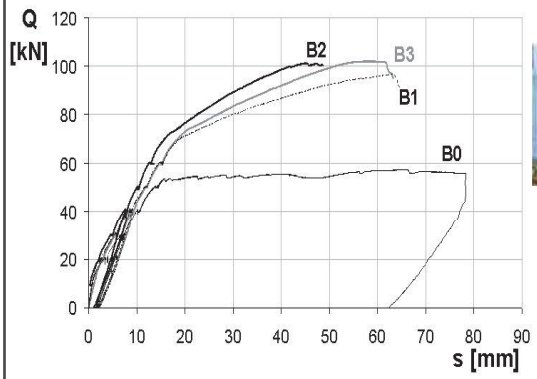
Test Results

Beam	P_y [kN]	P_y/P_{yB0} [%]	P_u [kN]	P_u/P_{uB0} [kN]	Δ_u [mm]	ε_u [%]	$\varepsilon_u/\varepsilon f_u$ [-]	Failure mode
B0	53.8	1.00	57.27	1.00	85.78	-	0.67	Yielding steel / concrete crush
B1	66.5	1.24	96.89	1.69	64.68	1.48	0.67	Debonding FRP
B2	67.8	1.26	101.46	1.77	48.67	1.07	0.67	Debonding FRP
B3	67.2	1.25	102.17	1.78	63.29	1.32	0.77	Debonding FRP



Concrete Crush

Debonding FRP

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Fire Insulations

Insulation	Insulation type	Density [kg/m³]	Conductivity [W/mK]	Application
Promat-H	Calcium silicate board	870	0.164	Mech. Fixed
Promat L-500	Calcium silicate board	500	0.09	Mech. Fixed
Aestuver	Glass fiber cement board	980	0.185	Mech. Fixed
WR-APP type C	Cementitious plaster	240	0.08	Spry applied
HPC/Omega	Ceramic coating	527	0.07	Spry applied

Spry applied

Mechanically fixed

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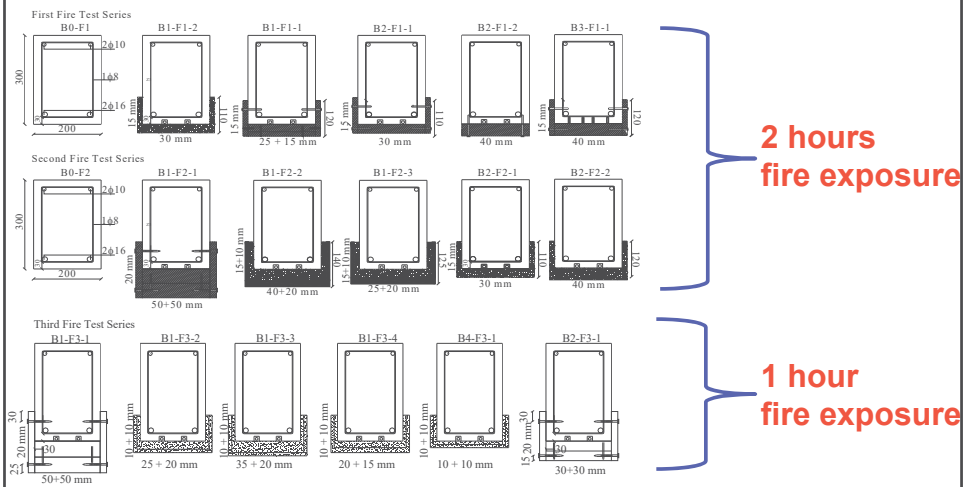
Fire Test Matrix



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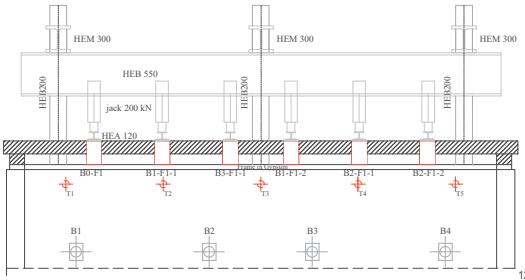
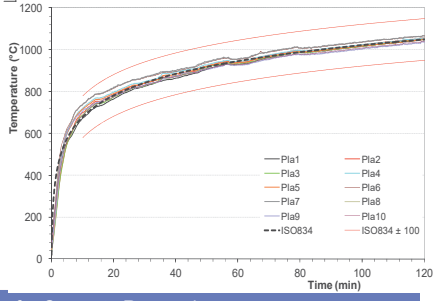
Test Set-up



The fire test is executed according to **EN 1363-1** standard fire test method

Heating according to **ISO 834** time temperature curve

$$T_{gs} = T_0 + 345\log_{10}(8t+1)$$



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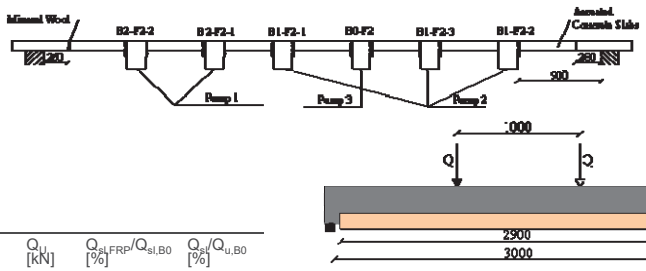
Load During Fire Test

Beams loaded to **service load**



Beam	Q_{sl} [kN]	Q_u [kN]	$Q_{sl,FRP}/Q_{sl,B0}$ [%]	$Q_{sl}/Q_{u,B0}$ [%]
B0	31.0	57.0	-	54
B1	36.0	96.5	116	63
B2	40.5	101.4	130	71

Q_{sl}= service load

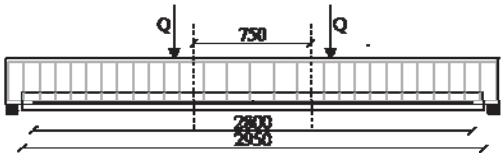
Q_u= ultimate load

$Q_{sl}/Q_{u,B0}$= % ultimate capacity of unstrength beam

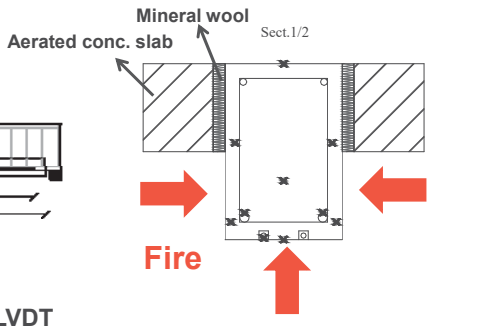
$Q_{sl,FRP}/Q_{sl,B0}$= % service capacity of unstrength. beam

Fire Tests Instrumentation

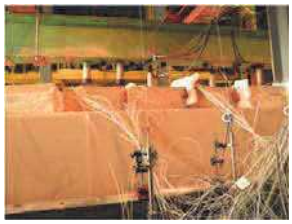
Thermocouple type K



4-point bending frame

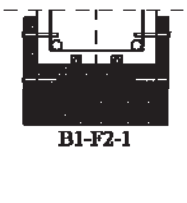


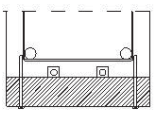
LVDT



Beams After Fire Exposure

Before test **After 2 hours fire exposure**





Insulation detached after 34 minutes

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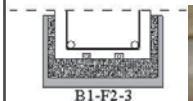
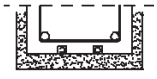
Beams After Fire Exposure (II)

Before test **After 2 hours fire exposure**





Crack due to the thermal shrinkage

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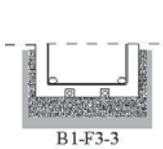
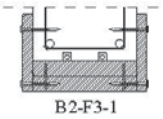
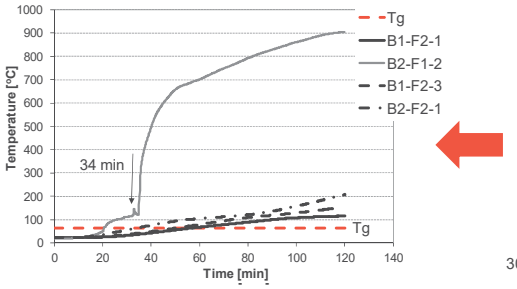
Beams After Fire Exposure (III)

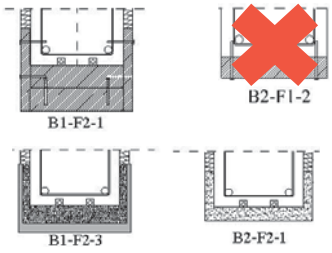
Before test **After 1 hour fire exposure**

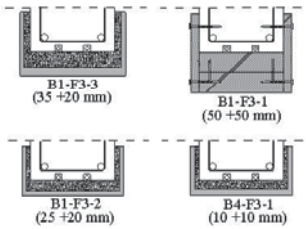


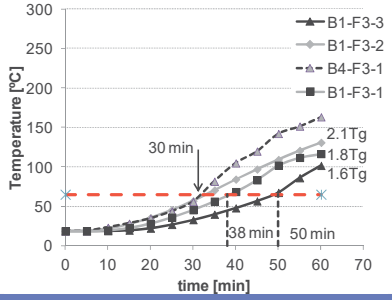


Test Results: Temperature Adhesive

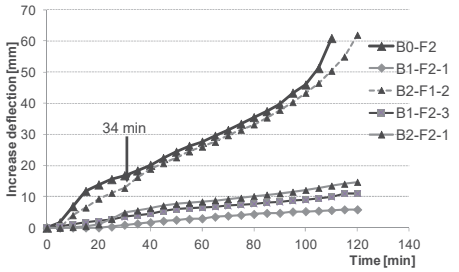


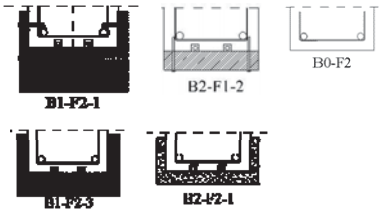


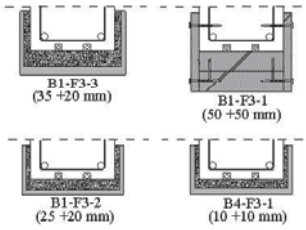


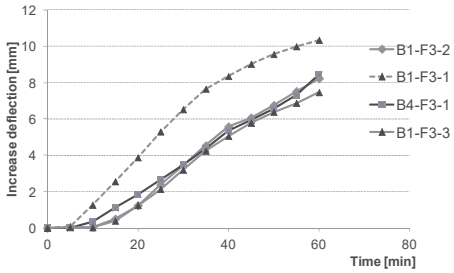


Test Results: Deflection Beams









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Fire Endurance

Exposure time	Beam	Insulation	$T_{concrete}$ [°C]	T_{steel} [°C]	$T_{adhesive}$ [°C]	$T_{Tadh=Tg}$ [min]
2 hours	B0-F1	-	120.0	611.0	-	-
	B1-F1-1	Promat-H	63.4	311.0	284.0	25
	B2-F1-1	Aestuver	88.0	372.0	611.0	21
	B2-F1-2	Aestuver	92.0	577.0	900.0	21
	B3-F1-1	Aestuver	77.0	325.0	547.0	22
2 hours	B0-F2	-	81.4	581,6	-	-
	B1-F2-1	Promat L-500	48.2	135.7	115.7	60
	B1-F2-2	HPC/Omega Fire	60.9	201.6	281.0	50
	B1-F2-3	HPC/Omega Fire	51.3	162.9	159.6	58
	B2-F2-1	WR- APP type C	53.9	222.9	207.3	44
	B2-F2-2	WR-APP type C	53.2	147.0	137.6	58
1 hour	B1-F3-1	Promat L-500	34.5	126.4	116.5	39
	B1-F3-2	HPC/Omega Fire	33.9	127.4	130.8	33
	B1-F3-3	HPC/Omega Fire	33.8	135.4	101.6	50
	B1-F3-4	HPC/ Omega Fire	34.5	122.0	101.2	37
	B2-F3-1	Promat L-500	39.2	135.2	110.9	38
	B4-F3-1	HPC/ Omega Fire	42.3	163.1	163.1	30

EN 1363-1

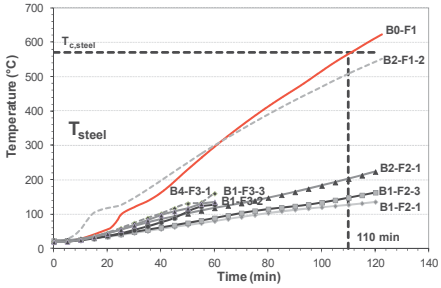
No failure under applied loads

$T_{Steel} \leq 570$ °C [1058 °F]

$T_{unexp.,av.} \leq 140$ °C [284 °F]

$T_{unexp.} \leq 180$ °C [356 °F]

T_{adh} at 1 and 2 hours of fire exposure ≥ T_g



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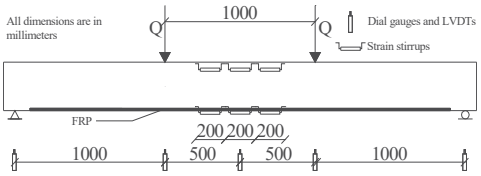
Residual Strength Test Set-up



4 –point bedding

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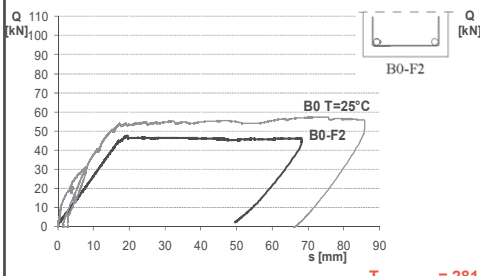
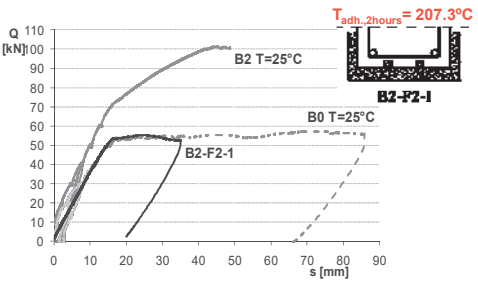
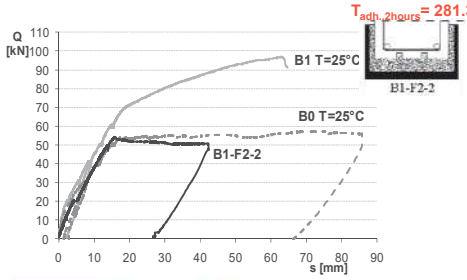
Residual Strength Test Results







Failure mode: Concrete Crush

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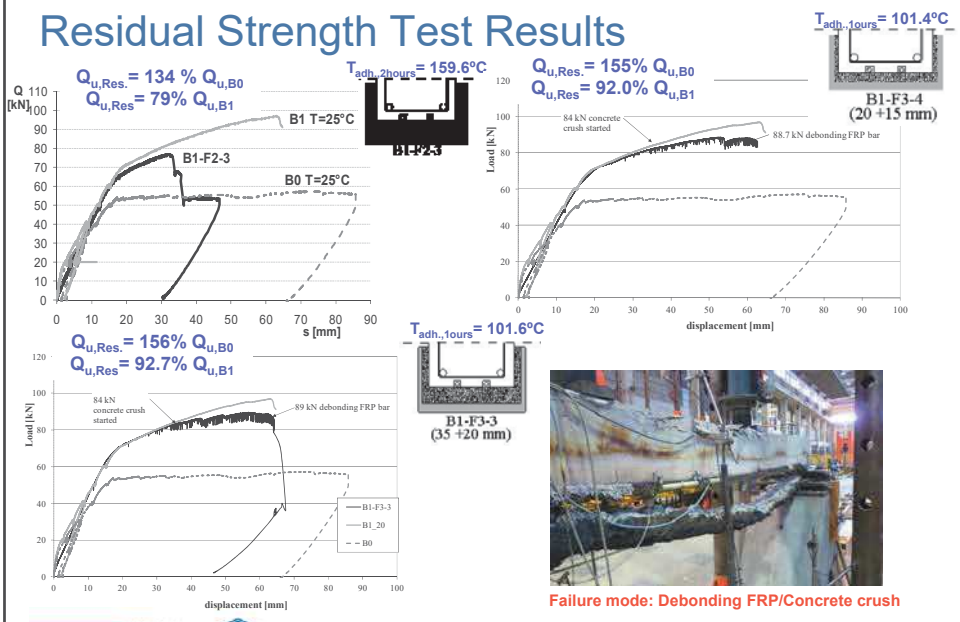
Residual Strength Test Results



Failure mode: Debonding FRP/Concrete crush

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Conclusions

- FRP strengthened beams can achieve up to **1 or 2 hours** fire endurance ratings under service load if well insulated.
- For none of the strengthened beams FRP NSM detached visibly, though temperature measurements may indicate reduced bond integrity after 34 to 120 minutes.
- Efficiency of fixation of the protection during fire appeared to have a large influence.
- The U shaped protection seems to be more efficient than the flat one.
- After fire exposure, the insulated beams were able to retain all of the original unstrengthened flexural capacity by maintaining the temperature of the concrete and steel respectively below 140 ºC and 570 ºC
- If the insulation is able to maintain the adhesive temperature at relatively low temperature (160 ºC for these tests), the FRP concrete bond degradation under fire is limited and the FRP strengthened beam is still able to retain a considerably part of the original strength (up to 97% for 1 hour fire exposure and 80% for 2 hours of fire exposure) .

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Acknowledgements

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Thank you for your attention

QUESTIONS ????????

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