

Fire Testing & Assessment of Reactive
Coatings:-

Requirements to meet UK and European
Approvals

Presentation to StIFF, Sheffield University

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UK and EN Requirements: Main Differences (1)

- UK testing is to BS476 pt21 – only a procedure to test loaded elements
- Furnace control is using K type wire thermocouples, using natural gas or LPG
- Loaded beams carry a segmented dense concrete slab in intimate contact with top flange
- Loaded beams are min 4m long, simply supported
- Loads applied should be calculated to induce the required bending and not be compromised by artificial effects (torsional buckling)
- Deflection criteria is L/20 or rate of deflection $L^2/9000d$ (when L/30 is reached)
- Loaded columns are min 3m tall
- No defined limit for structural failure, this occurs when column cannot support test load (a rapid change in the rate of column extension)
- Specimen T/C types are specified but not location or number
- No specification for testing short sections
- Testing of short sections are ad-hoc tests to BS476 pt20 and do not fully comply with the standard
- There is no guidance on assessment methods

UK and EN Requirements: Main Differences (2)

- Test programme for short sections to derive specifications across a range of A/V and performance times is promulgated by an industry body (ASFP/ICF)
- Specimen T/C's (location and number) are provided by the FTSG, **NOT** by any standard
- The test programme and assessment methods are laid out in ICF Industry guidance document (mirrored in ASFP Yellow Book)
- Loaded column tests are omitted if loaded beams are tested
- Loaded tests can fail if the element does not support the load for a min of 90% of the design fire resistance time
- Only a rudimentary graphical method is used for thermal assessments (very subjective) but a criteria of acceptability applied to test data has been introduced in recent years
- UK industry has introduced a test method for evaluating cellular beams separately from standard I beams

UK and EN Requirements: Main Differences (3)

- **EN testing is to BSEN 1363-1**, with detailed guidance in ENV 13381-4 and prEN 13381-8
- Furnace control is using plate thermometers, fuel can be gas or oil
- Loaded beams carry a segmented lightweight aerated concrete slab with insulation over the with top flange
- Loaded beams are min 4m long, simply supported
- Calculated bending moments account for web buckling – some lighter beams have a load insufficient to induce any significant bending
- Deflection criteria is L/30 or rate of deflection $L^2/9000d$
- Loaded columns are min 3m tall
- No defined limit for structural failure, this occurs when column cannot support test load (a rapid change in the rate of column extension)
- No time related failure criteria
- Specimen T/C types are specified in BSEN 1363 and location and number required are specified in 13381 pt4 and pt8
- pt4 AND pt 8 have detailed specifications for test package selection and assessment method
- EN standards introduce the requirement for correction of thermal data based on mechanical response of reactive coating (these corrections have recently been adopted by the UK industry guidance)

Main Differences between ENV 13381-4 and prEN 13381-8

- Number of fire tests on the short unloaded columns
- Number of thermocouples
- Criteria of acceptability
- Correction method (pt4 uses temperature, pt8 uses time)
- Choice of assessment method
- More flexibility for selection of design temperatures:-
 - Pt 4: max design temperature only (see section 6.1.1)
 - Pt 8: min and max design temperatures (see 13.5.1)
- Permitted extensions
- Details of assessment methods

Number of tests on the short unloaded columns

ENV 13381-4	prEN 13381-8
Dependent on assessment method	Dependent on the test package
Graphical method: 18	For I and H profiles: at least 13
Differential equation: 10	For hollow profiles: at least 6
Numerical regression: 10	

For I sections: 4 different section sizes each with min 3 dft's and 1 with 4 dft's, i.e.

$$n = (4 \times 3) + 1 \text{ (see table 6.6.3.1)}$$

For hollows: 3 different section sizes each with min 2 dft's (see table 6.6.3.2)



New requirement when assessing a thick layered reactive system (Interchar 212, an epoxy reactive coating) using the graphical method:-

- If $d_{\max} - d_{\min} > 5\text{mm}$
- then 6 dft thickness steps required and for each thickness step at least 3 different section factors (and 1 with 4 section factors), i.e.:-
- $n = (6 \times 3) + 1 = 19$ short sections

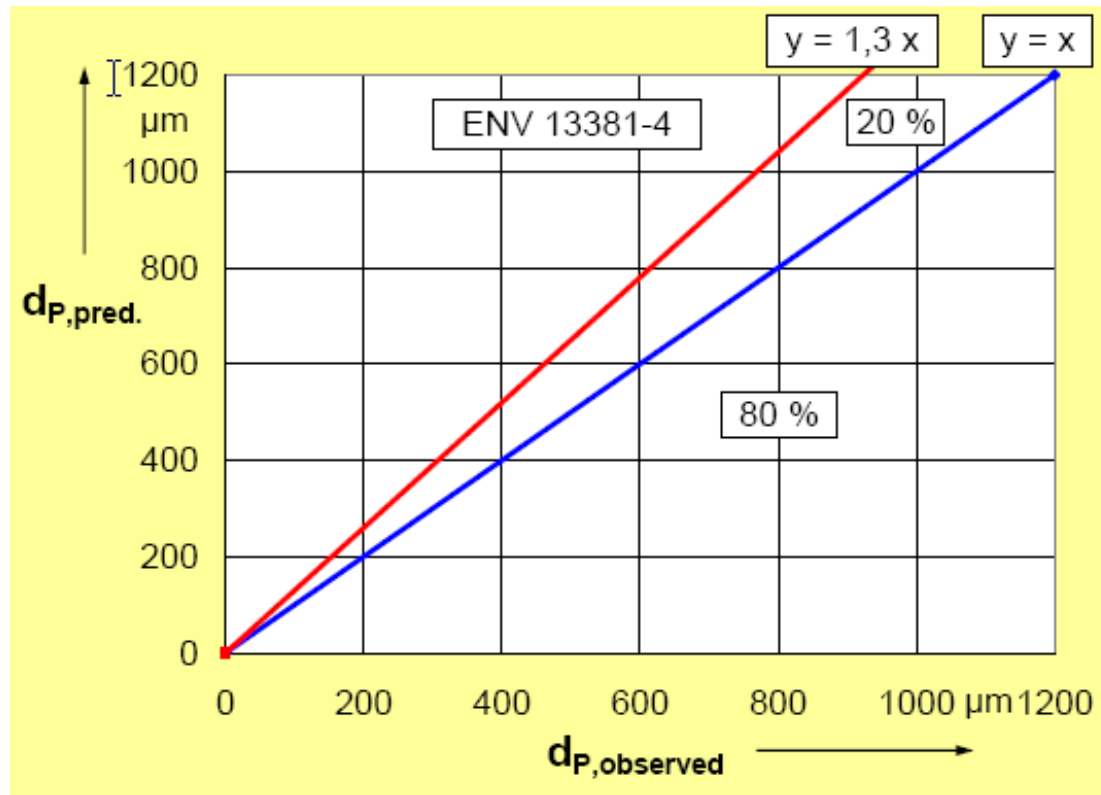
Number of thermocouples

Structural steel element Open profiles (I and H)	ENV 13381-4	prEN 13381-8
	Number of thermocouples	
Loaded beam	31	17
Unloaded reference beam	12	9
2 m tall column	30	15
Loaded Column	30	15
Short unloaded columns	10	9
Short unloaded beams	-	9

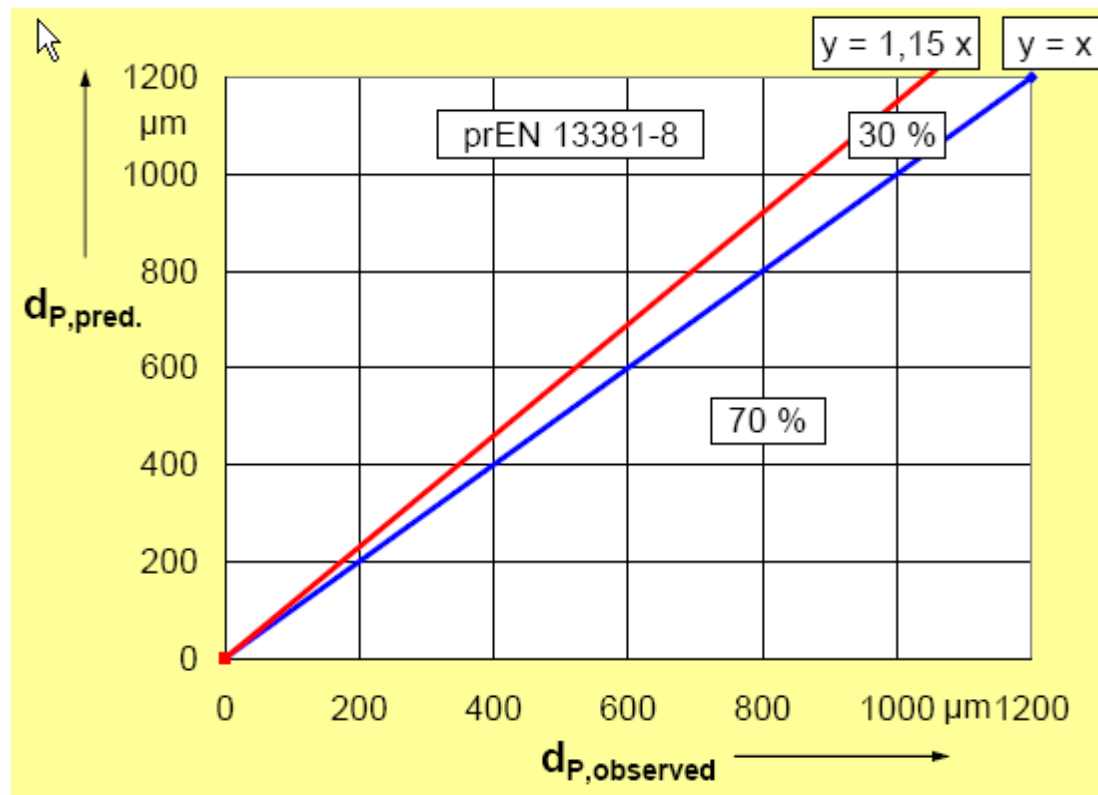
Number of thermocouples

Structural steel element Closed profiles (Hollow profiles)	ENV 13381-4	prEN 13381-8
	Number of thermocouples	
Loaded beam	-	11
Unloaded reference beam	-	9
2 m tall column	24	12
Loaded Column	-	12
Short unloaded columns	-	8
Short unloaded beams	-	9

Criteria of Acceptability - pt 4



Criteria of Acceptability - pt 8



Correction method:-

- Pt 4:-
Correction for temperature with correction factors, $k_d \geq 1.0$
- Pt 8:-
Correction for time to reach a specified design temperature with correction factors, $k_d \leq 1.0$
Method in pt 8 has been simplified from that in pt 4

Assessment Output:-

- Pt 4:-
 - Single assessment **only** for beams, or
 - Single assessment **only** for columns, or
 - Single assessment for beams **and** columns
 - No separate assessment for beams AND columns where these have been tested
- Pt 8:-
 - Separate assessment for beams AND columns

Single assessment only for beams (pt 4) or separate assessment (pt 8):-

- Calculate $k_{d,LB,min} = \theta_{LB,min} / \theta_{-c UB,min}$
- Calculate $k_{d,LB,max} = \theta_{LB,max} / \theta_{-c UB,max}$
- $k_{d,min} = k_{d,LB,min}$
- $k_{d,max} = k_{d,LB,max}$
- If $k_{d,min} = k_{d,max}$ use $k_d = k_{d,min}$ or $k_{d,max}$
- If $k_{d,min} \neq k_{d,max}$ interpolate between $k_{d,min}$ and $k_{d,max}$

Single assessment for beams and columns (pt 4) or separate assessment for columns (pt 8) only when loaded beams are tested:-

- Calculate $k_{d,LB,min} = \theta_{LB,min} / \theta_{-c UB,min}$
- Calculate $k_{d,LB,max} = \theta_{LB,max} / \theta_{-c UB,max}$
- Calculate $k_{d,TC,max} = \theta_{TC,max} / \theta_{-c SC,max}$
- $k_{d,min} = k_{d,LB,min}$
- $k_{d,max} = \text{worst case of } (k_{d,LB,max}, k_{d,TC,max})$
- If $k_{d,min} = k_{d,max}$ use $k_d = k_{d,min}$ or $k_{d,max}$
- If $k_{d,min} \neq k_{d,max}$ interpolate between $k_{d,min}$ and $k_{d,max}$

Single assessment for columns (pt 4) or separate assessment for columns (pt 8):-

- Calculate $k_{d,LC,min} = \theta_{LC,min} / \theta_{-c UC,min}$
- Calculate $k_{d,LC,max} = \theta_{LC,max} / \theta_{-c UC,max}$
- $k_{d,min} = k_{d,LC,min}$
- $k_{d,max} = k_{d,LC,max}$
- If $k_{d,min} = k_{d,max}$ use $k_d = k_{d,min}$ or $k_{d,max}$
- If $k_{d,min} \neq k_{d,max}$ interpolate between $k_{d,min}$ and $k_{d,max}$

Design Temperatures

- Pt4:-
 - Selection of highest design temperature θ_D , in steps of 50°C from 350°C to 750°C
- Pt8:-
 - Lowest and highest θ_D can be selected, in the range 350°C to 750°C, but at least 3 design temperatures in steps of 50°C

Permitted Extensions

		Variable λ	Fixed λ	Regression	Graphical
Pt4	dft	+/- 20%	+/- 5%	+/- 5%	0%
	A/V	+ 50%, - 20%	+ 50%, - 20%	+/- 10%	
	θ	+ 10%, - 0%	+ 7.5%, - 0%	+ 5%, - 0%	
Pt8	dft	Beams: + 5% of d_{max} LB, - 5% of d_{min} LB Cols: + 5% of d_{max} LC, TC, - 5% of d_{min} LC or d_{min} unloaded column			
	A/V	Beams and cols: +/- 10% of any short section tested			
	θ	Not allowed			

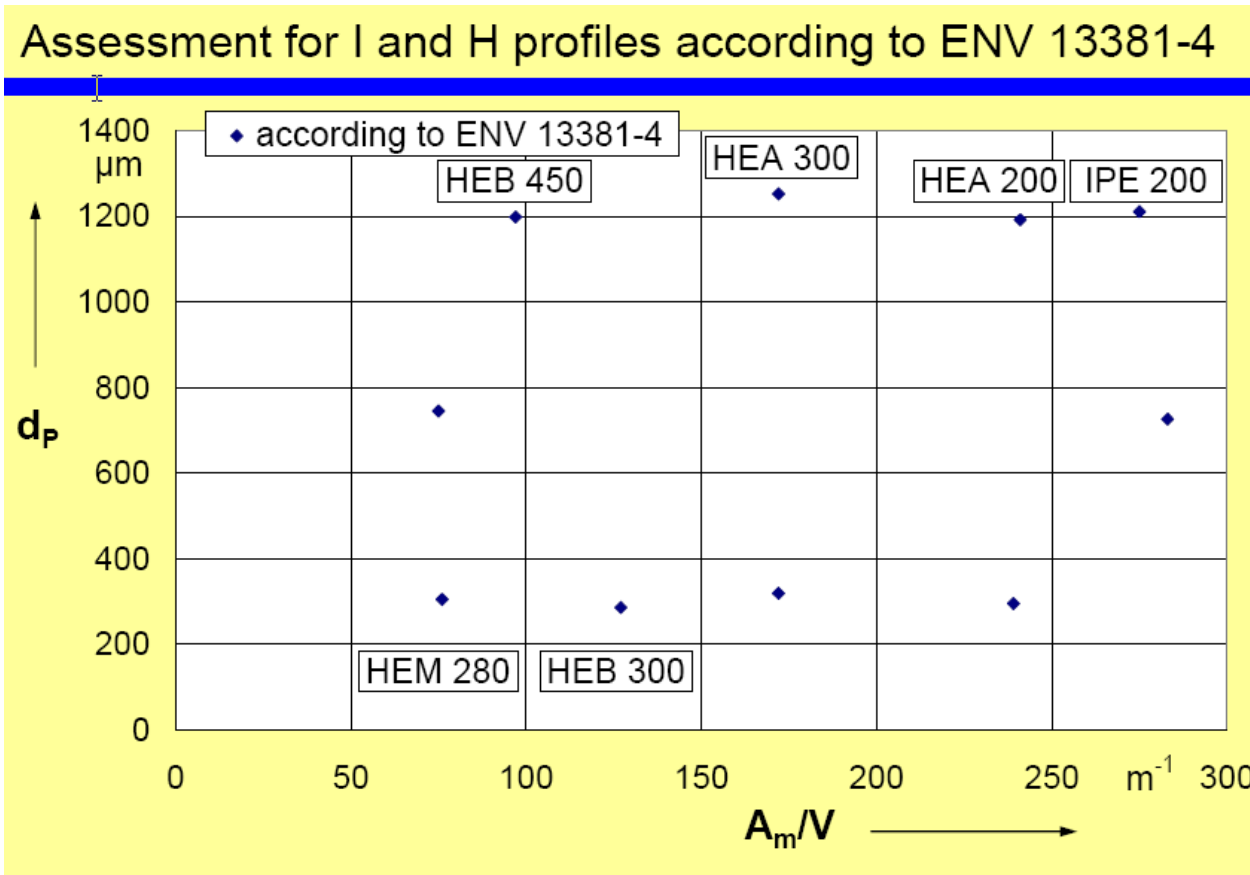
Assessment Methods

- All changed except the regression method

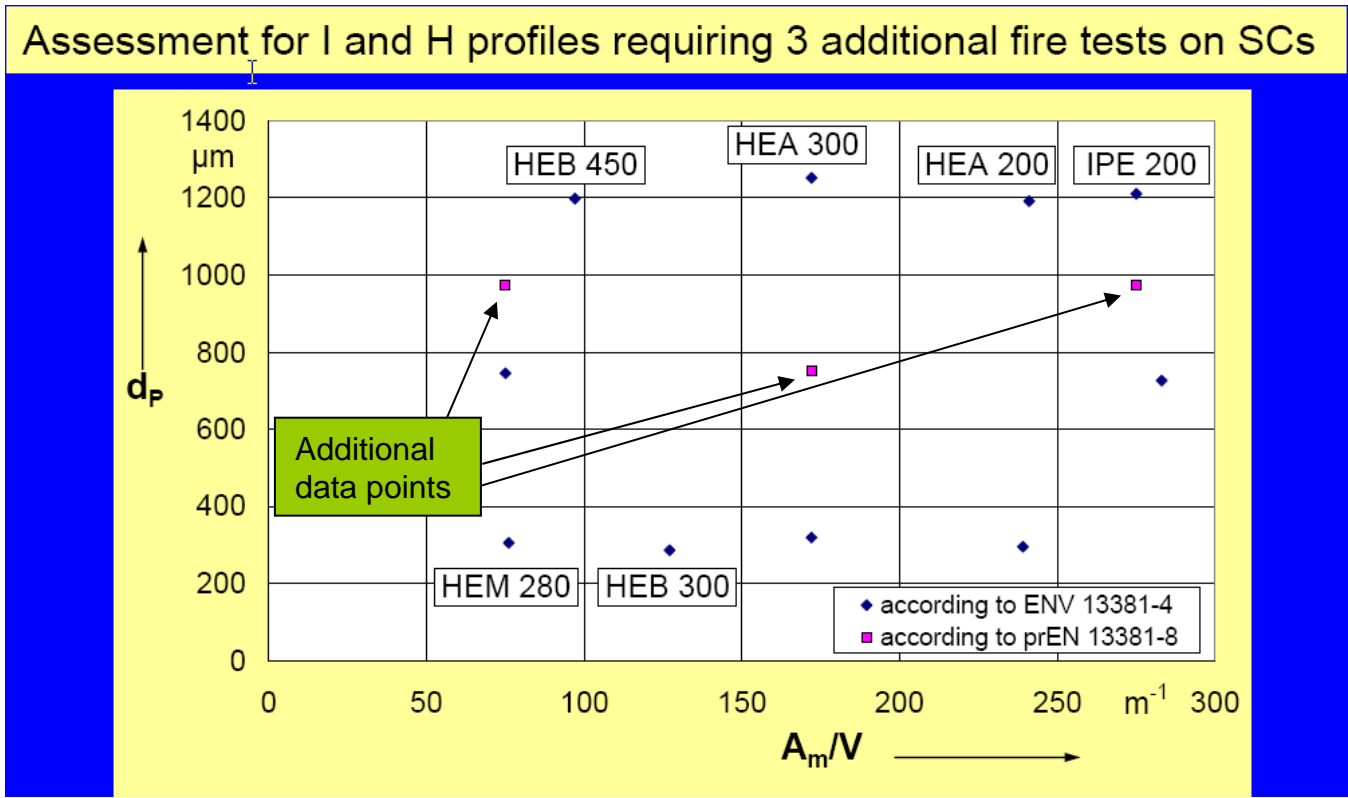
Assessment to pt8 using test data from pt4:-

- An assessment for I and H profiles requires at least 3 additional fire tests on short unloaded columns as the number of short unloaded columns has been changed from 10 to 13
- In most cases it will be necessary to make two separate assessments, one for beams and one for columns, unless the correction factors $k_{d,LB,min}$, $k_{d,LB,max}$ and $k_{d,TC,max}$ are identical
- For an assessment of hollow beams we recommend to use test package 14 with 2 loaded hollow beams and 6 short hollow beams (additional fire tests)
- For an assessment of hollow columns we recommend to use test package 15 with 2 loaded hollow columns, 2 tall hollow columns and 6 short hollow columns (additional fire tests)

Test Requirements for Interchar 404

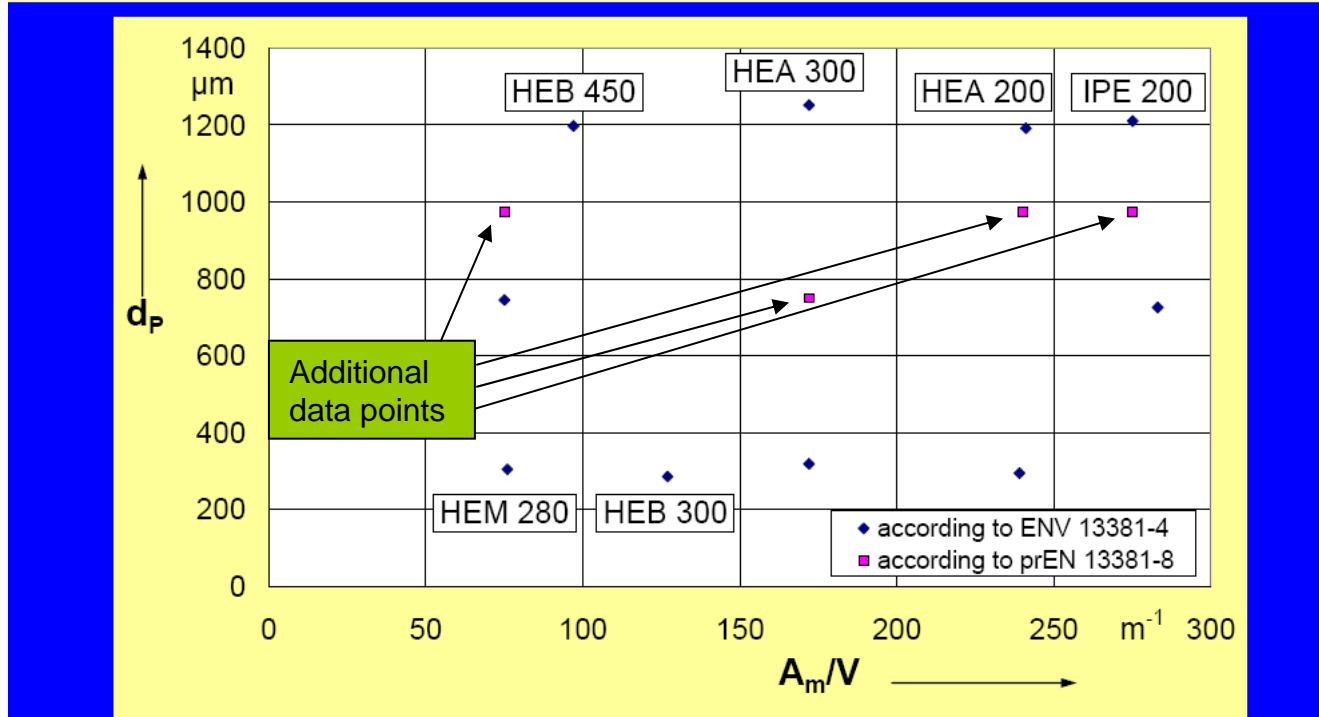


Test Requirements for Interchar 404



Test Requirements for Interchar 404

Assessment for I and H profiles requiring 4 additional fire tests on SCs



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