Addition method

General

The following method is not 100 % exact and does not compensate real fire tests. There are still too many unsure parameters. The result of such a calculation can be used as complement to the testing or a reference test can complete the calculation.

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The addition method is a method for calculating the fire resistance of timber structures with wooden studs and the highest fire-engineering class of EI 60. By adding the fire resistance of the structure's various material layers it is possible to get an estimate of the entire structure's fire resistance (b_{tot}). The calculations are based on a large number of fire tests. The starting point is the so-called base value (b_n). This is the fire resistance of a material layer. The location of the layer in the structure can be established by multiplying the base value with a position coefficient (k_n). The following formula can also be used.

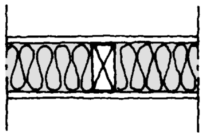
$$b_{tot} = b_1k_1 + b_2k_2 + \ldots = \Sigma b_nk_n \qquad \text{(formula 1)}$$

Examples of a material's base value (b) and position coefficient (k) are shown in the table below.

Base value (b_n) of various materials

Type	Density (kg/m³)	Thickness (mm)	Base value (min)
Wood based boards and all plywood	450–590	12 20	11.1 18.7
Chip boards and fibre boards	600–800	12 22	13.6 24.6
Gypsum board Normal Protect F	 680–780 ≥830	 13 15	 18.0 22.0
Glass wool	19	45 95 120 195	5.0 10.0 12.0 20.0
Stone wool	28	45 95 120 195	9.0 19.0 24.0 39.0
Air gap		45–195	5.0

A sample calculation.
Here is an example of fire resistance (b_{tot}) calculated according to the Addition method (formula 1).



(A) Air gap
b_{tot}=(13.6 x 0.8)+(5.0 x 1.0)+(13.6 x 0.6)= 24.0 min

(B) Glass wool
b_{tot}=(13.6 x 0.78)+(10.0 x 1.0)+(13.6 x 0.67)=29.7 min

(C) Stone wool
b_{tot}=(13.6 x 0.78)+(19.0 x 1.0)+(13.6 x 2.9)= 69.0 min

Position coefficient (k_n) for various material layers in a wall with a single board layer.

Type	Thickness (mm)	Position coefficients								
		Exposed board cover on rear with			Non-exposed board covered on front with					
		Glass wool / stone wool (mm) 45–195	Air gap	Ins / air gap	*)1)Glass wool (mm) 45–195	Stone wool (mm) 45	70	95	145	2)3) Air gap
Wood based board and all plywood	12	0.78	0.8	1.0	0.67	1.9	2.4	2.9	3.9	0.6
	20	0.94	0.8	1.0	1.23	1.9	2.4	2.9	3.9	0.6**)
Chip and fibre boards	12	0.78	0.8	1.0	0.67	1.9	2.2	2.9	3.9	0.6
	22	0.98	0.8	1.0	1.37	1.9	2.4	2.9	3.9	0.6**)
Gypsum board Normal	13	0.80	0.8	1.0	0.74	1.9	2.4	2.9	3.9	0.7
Gypsum board Protect F	15	0.84	0.8	1.5[4)]	0.88	1.9	2.4	2.9	3.9	0.7

*) With regard to thickness of the exposed board.
**) 0.8 when stud spacing is ≥ 70 mm.

When Protect F or equivalent is used as the exposed board, i.e. the board resists fire ≥ 60 minutes, the following position coefficients can be applied:

1) The same as for stone wool, however max. 2.9.
2) 1.5 for wood-based boards.
3) 1.8 for gypsum board and fibre cement boards.
4) 2.0 for glass wool

Position coefficients (k_n) for various materials layers in walls with two board layers.

Structure[2] Exposed / non-exposed board + board closest to stud	Exposed board: board 1 exposed	Exposed board: board 2 closest to stud	Isolation / air gap	Non-exposed boards: board 3 closest to stud	Non-exposed boards: board 4 non-exposed
2 x wood-based board air gap	1.0	0.6	1.0	0.5	0.7
2 x gypsum board air gap	1.0	1.0	1.0	1.0	0.7[3]
Gypsum + wood-based board air gap	1.0	1.0	1.0	0.8	0.7[3]
Wood-based board + gypsum air gap	1.0	0.6	1.0	1.0	0.7[3]
2 x wood-based board stone wool, 28 kg / m³	1.0	0.6	1.0	1.0[1]	2.0[1]
2 x gypsum board stone wool, 28 kg / m³	1.0	1.0	1.0	1.0[1]	3.5[1]
Gypsum + wood-based board stone wool, 28 kg / m³	1.0	1.0	1.0	1.0[1]	2.0[1]
Wood-based board + gypsum stone wool, 28 kg / m³	1.0	0.6	1.0	1.0[1]	2.5[1]

[1] The value is clearly on the safe side. To obtain higher values more base layer is required.
[2] Total board thickness max 26 mm per side of wall.
[3] 1.0 when stud spacing ≥ 70 mm.

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Addition method - Complementary data for Paroc stone wool

The base values for materials were obtained through an extensive test programme, in which samples were tested both in full and reduced scale. In order to complement the study and mainly to study the influence of stone wool density we initiated a test project at the Swedish Institution for Technical Education in Norrköping. The methods used were the same as the first ones used by Trätek. Some tests were carried out in parallel, and they proved to be compatible. The results are shown in the tables below.

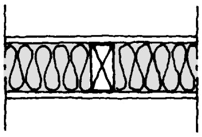
Base values (b_n) for various Paroc stone wool products and for Gyproc Normal gypsum board

Product number	Density (kg / m³)	Thickness (mm)	Base value (min)
Gypsum board	730	13	18.7
PAROC UNS 37	26	45 70 95 145	7.7 10.9 11.6 20.3
PAROC FPS 4	45	45 70 95	10.4 16.8 20.2
PAROC COS 10	80	50 80 100	12.6 24.5 32.3
PAROC FPS 14	140	30 50 70 80	11.9 23.5 38.0 43.7

Position coefficients (k_n)

Type	Thick-ness (mm)	Position coefficient: Exposed lined board with stone wool on back side	Stone wool density (kg / m³)	Stone wool	Position coefficients: Non-exposed lined board with stonewool on front side, thickness (mm) 30	45	50	70	80	95	100	145
Gypsum board	13	0.9	26	1.0	–	2.1	–	2.6	–	2.9	–	3.5
		0.9	45	1.0	–	2.3	–	2.7	–	3.3	–	–
		0.9	80	1.0	–	–	3.1	3.5	–	4.1	4.3	–
		0.9	140	1.0	2.6	–	3.6	4.1	4.3	–	–	–

NB. (-) = no data available.



13 mm gypsum board
95 mm PAROC slab
45 x 95 mm stud c 600 mm
13 mm gypsum board

A sample calculation.
Here are sample calculations of the structure described above as per (formula 1) on page 41.

(D) PAROC UNS 37 (26 kg/m^3)
b_{tot} = (18.7 x 0.9)+(11.6 x 1.0)+(18.7 x 2.9)= 82.7 min

(E) PAROC FPS 4 (45 kg/m^3)
b_{tot} = (18.7 x 0.9)+(20.2 x 1.0)+(18.7 x 3.3)= 98.7 min

Addition method –
Fire resistance period over 60 mins

According to the above calculations long fire resistance periods are obtained when using stone wool as insulation. These periods are usually longer than the fire-engineering classes given in other information material from Paroc. Why? In a fire the inner lining either burns or falls down – usually after the fire has been burning for 15 to 25 minutes. After that the studs and the isolation are exposed to fire. Withstanding temperatures of over 1,000 °C stone wool stays in place and protects the non-exposed skin plate. The studs are charred at a rate of 0.7–1.0 mm per minute, and will thus be consumed in about 100 minutes. Oversized insulation units are commonly clamped between the studs, but as the studs burn off, the insulation falls down. After that the fire will penetrate the non-exposed board. As this process can vary from case to case, it is disregarded when calculating the fire resistance. This is why certain care is required when making such calculations. This is also the main reason why the Addition method may not be used when the burning time exceeds 60 minutes.

Another reason for lower fire-engineering classes is that the fire resistance period is rounded down to the closest value. In example D above 82.7 minutes is reduced to 60 minutes.

Other Paroc information regarding fire

Instruction for how to insulate steel structure against fire are to be found on our web pages. There will also other tested and approved constructions be found, depending on how far the implementation of the EN-regulations have gone in different countries.

For further information of material properties and our products see www.paroc.com