BRANDSKYDDSLAGET

Stockholm 2023-01-20

POSI–JOIST and FIRE PROTECTION

Fire engineering analysis including the impact of ventilation ducts in the Posi floors

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Contents

1 Background and assumptions

Posi–Joist floor is a lightweight floorsystem constructed with wooden-rules/beams, steel-diagonals (Posi-struts), gypsum boards and mineral wool insulation.

The special thing about the joists are the load-bearing beams. They consist of a hybrid construction consisting of a lower and upper flange of wood (normal dimension 45 x 95 mm) which is connected by diagonals of thin sheet metal. See principle according to figure 1.

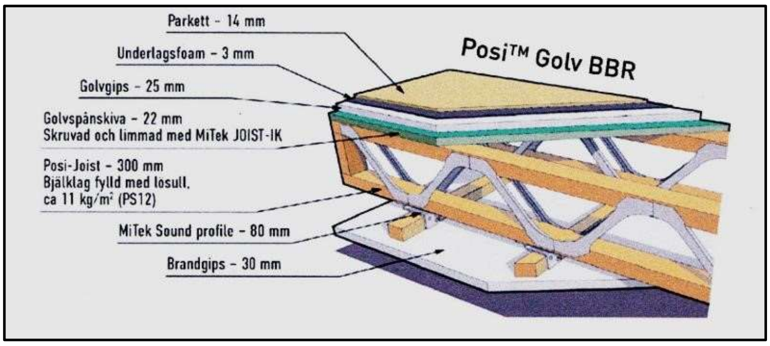


Figure 1

The floor structure according to the figure is protected from below with 2 x 15 fire plaster boards and meets the fire technical class REI 60. The bearing capacity in case of fire (R 60) is based on the bottom flange not carbonizing too much in the event of a fire from below, without a large enough part of the bottom flange's cross-section being unaffected so that the beam is able to carry current loads for the load case fire. With 2 x 15 fire plaster boards this is not a problem. Calculations show that even R 90 is met with 2 x 15 fire plaster boards. See further section 3.2

The joist layer according to figure 1 is filled with stone wool-type loose wool. See figure 2.

Figure 2

A membrane/ground cloth is attached to the lower flanges of the beams, which means that no insulation is added between plasterboard and the underside of the lower flange of the beams. There is thus an 80 mm free air space between the plasterboard and the underside of the beams.

The joist can be delivered to the construction site with its upper part as shown in Figure 3 and there supplemented from below with a suspended false ceiling of plasterboard, whereby the loose wool insulation is also filled in at the construction site. Another option is for ready-made cassettes to be manufactured in a factory, including false ceilings and loose wool insulation. See figure 2.

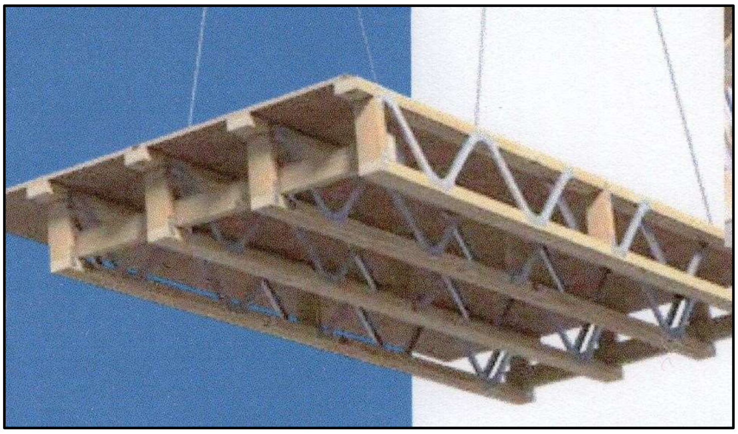


Figure 3

A clear advantage of the current joists compared to many other light joists on the market is that the open diagonals make it easy to draw ventilation ducts in the joists without having to cut holes in the supporting structures. See Figure 4.

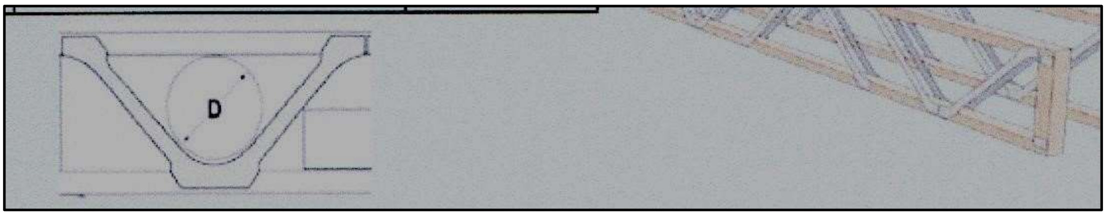


Figure 4

In general, however, ventilation ducts laid within a joist can mean certain fire-technical problems that must be taken care of. It is common for ventilation ducts laid in the joists to supply the underlying apartment. See principle according to figure 5.

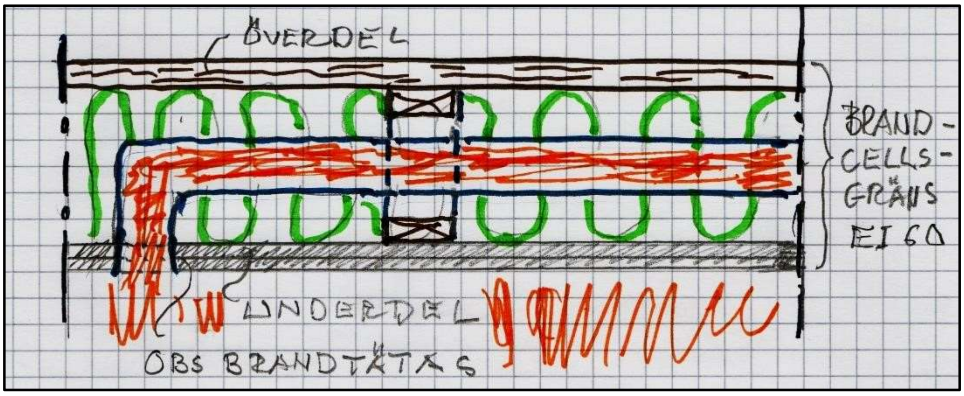


Figure 5

Since the joist forms a fire cell limit (EI 60), this limit includes the entire joist construction, i.e. both the lower part in the form of plasterboard and the upper part in the form of floor as well as intermediate insulation.

According to the figure above, the ventilation channel basically means that you move heat from the fire locally into the middle of the joist. However, the ventilation duct does not burn to pieces or melt, but the temperature from the fire can be assumed to be "encapsulated" in the sheet metal duct. It is, however, important that the holes for the channel through the gypsum boards of the lower part are properly fire-sealed so that leaks do not cause the fire to enter directly into the joists through such leaks. Then a completely different situation can arise.

It should also be noted that there is a difference between supply air and exhaust air ducts. It is common today for FTX systems to dimension the system to be operational in the event of a fire. Properly dimensioned and executed, the risk of fire and fire gas spreading is limited via a ventilation system common to several fire cells. A **supply air duct** that is built into the joist then in principle transports 20 degree air to the burning fire cell and any hot fire gases are not drawn into the duct at all. However, the channel can be heated for a shorter distance closest to the fire through heat conduction in the plate. However, the plate temperature decreases after a short distance and any fire-technical measures such as insulation of the duct can then normally be limited in length.

In the case of **exhaust ducts** and fans in operation, however, hot fire gases are constantly drawn into the duct. However, it does not burn in the duct itself, but rather the hot fire gases from the fire cell are transported in the duct. This means that heat is gradually lost and the further away from the fire, the lower the temperature in the duct. On the other hand, the insulation that the duct must have at least at the beginning of the duct in order not to risk igniting combustible constructions means that the temperature drop along the duct will be relatively limited. This means that exhaust ducts built into joists as above must normally have sufficient protection against or distance from combustible parts along their entire length.

2 General about fire engineering dimensioning of constructions

In general, the fire resistance of a fire barrier and/or a load-bearing structure may be determined by
* Trials
* Calculations
* Combination of trials and calculations

In the Eurocodes for concrete, steel, composite and wooden constructions, there are instructions for calculating the fire resistance of various constructions. Usually, the temperature of the structure is calculated for a given fire class requirement, e.g. EI 60 for a separating structure or R 60 for a load-bearing structure when the structure is exposed to a standard fire impact according to ISO 834.

For separating constructions, the temperature increase on the side not exposed to fire must not exceed 140 degrees on average after the prescribed time, e.g. 60 minutes. At a starting temperature of 20 degrees, this means a permissible temperature on the non-fire side of the wall of 160 degrees.

For load-bearing constructions - in the current case the wooden constructions as above - it applies that the residual cross-section of wooden studs and wooden beams after charring during 60 minutes of standard fire exposure must have a bearing capacity that is greater than the current load in the case of fire.

In order to be able to make calculations as above, the thermal data of the materials included in the construction, such as thermal conductivity and specific heat capacity and their variation with temperature, must be known. The thermal conductivity increases with increased temperature for the vast majority of materials. For stone wool products, for example, the thermal conductivity increases more for light products compared to heavier ones, even if the thermal conductivity is the same at room temperature.

Thermal conductivity numbers and specific heat capacity as a function of temperature are specified in the Eurocodes for concrete, steel and wood and these values can thus be used as input data when calculating fire resistance as above. For e.g. stone wool and glass wool there is corresponding data reported in *Fire Safety in timber buildings*.

Thermal data for plasterboard, including the effect of the plasterboard's disintegration, has been produced by the Fire Protection Team and verified to be on the safe side through comparisons over a long period of time with a large number of fire tests on various constructions with plasterboard.

For Fermacell Fibergypsum, thermal data have been determined through comparisons with fire tests on different wall types. See the Fire Protection Team's report: *Fermacell - Fire engineering dimensioning of shaft walls, Stockholm 2015-10-10.*

The temperature in a structure exposed to fire can be calculated with the two-dimensional heat conduction program TASEF (Temperature Analysis of Structures Exposed to Fire) developed by Professor Ulf Wickström. Ulf Wickström was previously long-term manager at the SP (RISE) fire testing laboratory in Borås, and the TASEF program has been used and verified against a large number of fire tests.

In the TASEF calculation, the cross sections are divided into a number of elements using node lines. The program then successively calculates during the fire the temperatures in each node, taking into account the thermal data of the constituent materials and their variation with temperature.

Based on calculated temperatures in the load-bearing wooden studs, the charring depth can be determined. According to Eurocode 5 (EN 1995-1-2), the carbonization limit corresponds to the 300 degree isotherm. According to the same Eurocode, an additional 7 mm, corresponding to a zone with no or very little strength, should be subtracted from the charring limit in order to obtain the so-called effective cross-section for which full strength may be assumed. According to previous investigations by the undersigned - based on comparisons between measured temperatures and real breaking loads and calculated temperatures and breaking loads in a large number of fire tests - these 7 mm can be replaced with the 200 degree isotherm.

See report:
Fire resistance of load-bearing wooden stud walls. Proposal for a fire engineering dimensioning method and comparison with performed fire tests on loaded wooden stud walls. SBUF Development project 13442/ 2018.

Below, calculations are made as above for the Posi-Joist joist with different conditions both without and with ventilation ducts laid in the joist.

3 Temperature calculations

3.1 General

In figure 6 is shown a principle section of the Posi-Joist joist with Posi-Joist beams at a center distance of 600 mm.

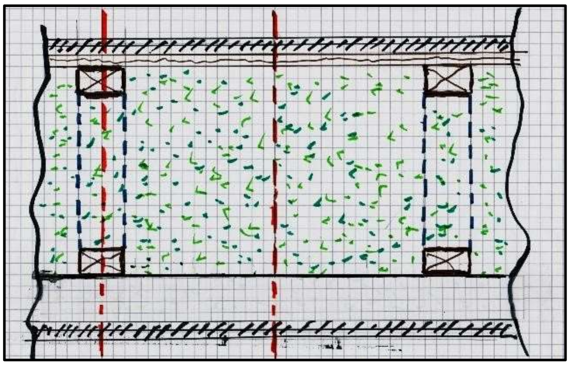


Figure 6

For the TASEF calculation, it is sufficient to calculate the cross-section between the red lines that constitute lines of symmetry. Namely, no heat exchange takes place across lines of symmetry.

3.2 Floor joists with 2 x 15 mm fire-resistant plasterboard on the underside without a ventilation duct

In figure 7 is shown selected node division for the TASEF calculation. Total number of node points is 180.

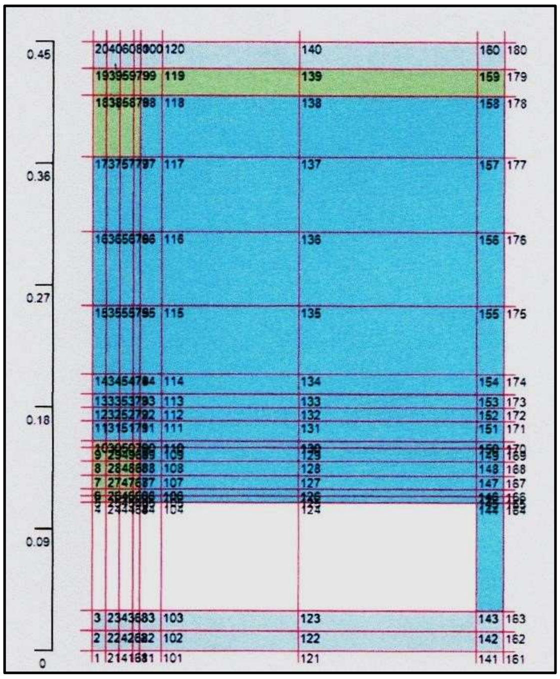


Figure 7

In figure 8 a temperature image is shown after 60 minutes of standard fire exposure.

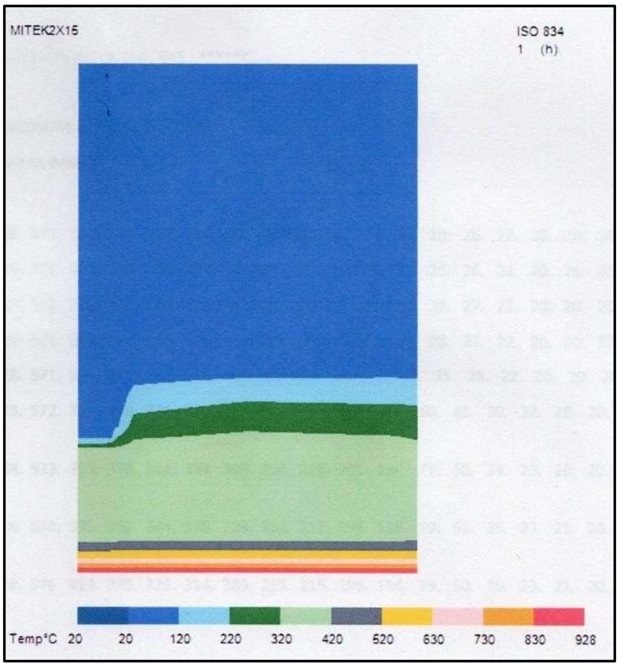
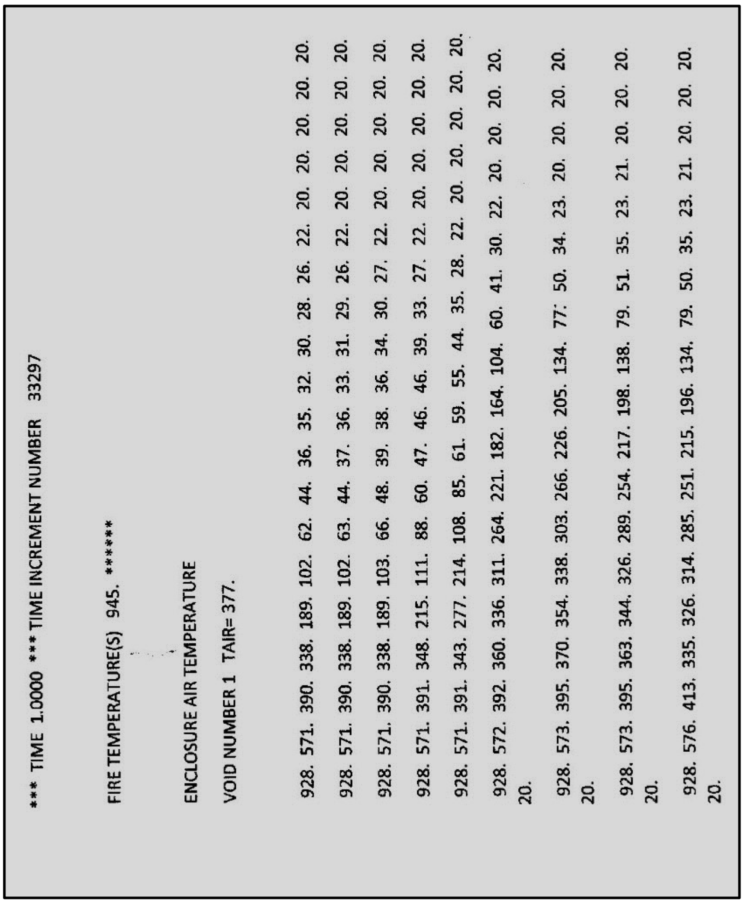


Figure 8

Calculated temperatures after 60 minutes in each node point are shown in Figure 9.



```
*** TIME 1.0000 *** TIME INCREMENT NUMBER   33297

FIRE TEMPERATURE(S)  945.  ******

ENCLOSURE AIR TEMPERATURE

VOID NUMBER 1  TAIR= 377.

928. 571. 390. 338. 189. 102. 62. 44. 36. 35. 32. 30. 28. 26. 22. 20. 20. 20. 20. 20.
928. 571. 390. 338. 189. 102. 63. 44. 37. 36. 33. 31. 29. 26. 22. 20. 20. 20. 20. 20.
928. 571. 390. 338. 189. 103. 66. 48. 39. 38. 36. 34. 30. 27. 22. 20. 20. 20. 20. 20.
928. 571. 391. 348. 215. 111. 88. 60. 47. 46. 46. 39. 33. 27. 22. 20. 20. 20. 20. 20.
928. 571. 391. 343. 277. 214. 108. 85. 61. 59. 55. 44. 35. 28. 22. 20. 20. 20. 20. 20.
928. 572. 392. 360. 336. 311. 264. 221. 182. 164. 104. 60. 41. 30. 22. 20. 20. 20. 20.
20.
928. 573. 395. 370. 354. 338. 303. 266. 226. 205. 134. 77. 50. 34. 23. 20. 20. 20. 20.
20.
928. 573. 395. 363. 344. 326. 289. 254. 217. 198. 138. 79. 51. 35. 23. 21. 20. 20. 20.
20.
928. 576. 413. 335. 326. 314. 285. 251. 215. 196. 134. 79. 50. 35. 23. 21. 20. 20. 20.
20.
```

Figure 9

Using the temperatures in Figure 9, the 200 degree isotherm has been constructed and superimposed over the rule cross-section in Figure 10.

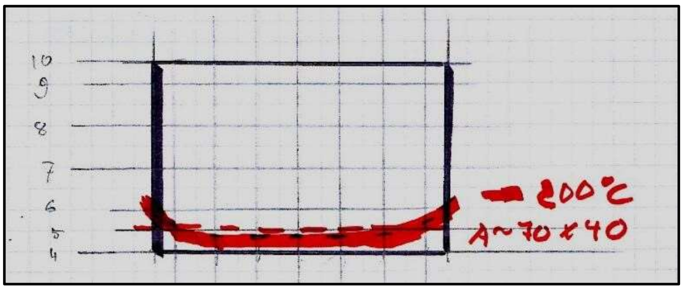


Figure 10

The cross-section has barely started to char (300 degrees) and the effective cross-section (200 degrees) corresponds to an area of approx. 70 x 40 mm. This is 70x40/70x45 or about 90% of the original area. Dimensioning strength in case of fire load is significantly higher than design strength in case of breaking load dimensioning at the same time that dimensioning load in case of fire load is about half of dimensioning load in case of breaking load dimensioning. This means that one can immediately state that the reported design of the Posi-Joist joist with 2 x 15 mm fire gypsum board on the underside meets the fire technical class REI 60 with a margin.

The corresponding calculation for 90 minutes of standard fire exposure (REI 90) is made.

Figure 11 shows a temperature picture after 90 minutes of standard fire exposure.

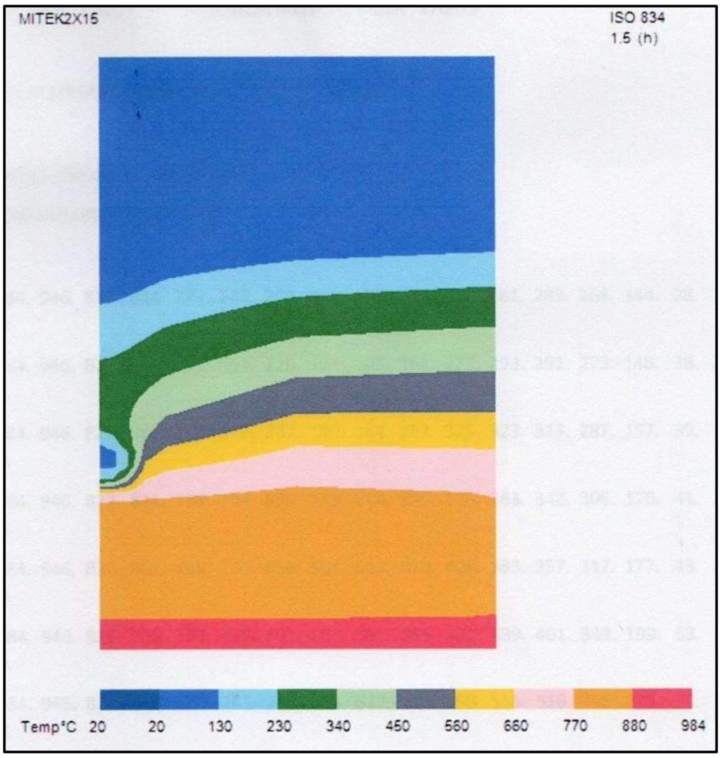
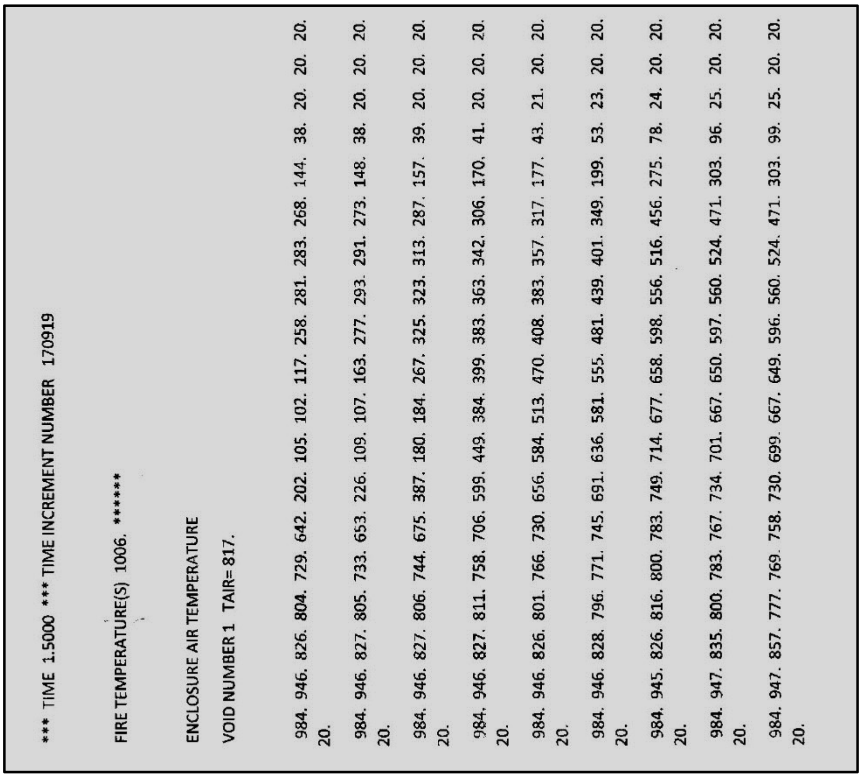


Figure 11

Calculated temperatures after 90 minutes in each nodal point can be seen in Figure 12.



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***  TIME  1.5000  ***  TIME INCREMENT NUMBER   170919

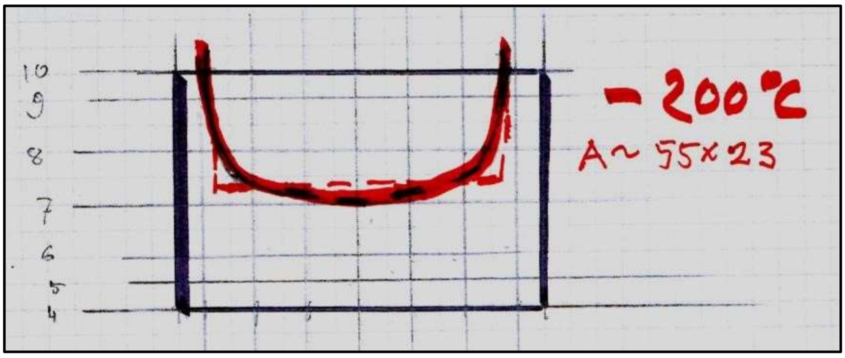
FIRE TEMPERATURE(S)  1006.  ******

ENCLOSURE AIR TEMPERATURE
VOID NUMBER 1   TAIR= 817.

984.  946.  826.  804.  729.  642.  202.  105.  102.  117.  258.  281.  283.  268.  144.  38.  20.  20.  20.
20.
984.  946.  827.  805.  733.  653.  226.  109.  107.  163.  277.  293.  291.  273.  148.  38.  20.  20.  20.
20.
984.  946.  827.  806.  744.  675.  387.  180.  184.  267.  325.  323.  313.  287.  157.  39.  20.  20.  20.
20.
984.  946.  827.  811.  758.  706.  599.  449.  384.  399.  383.  363.  342.  306.  170.  41.  20.  20.  20.
20.
984.  946.  826.  801.  766.  730.  656.  584.  513.  470.  408.  383.  357.  317.  177.  43.  21.  20.  20.
20.
984.  946.  828.  796.  771.  745.  691.  636.  581.  555.  481.  439.  401.  349.  199.  53.  23.  20.  20.
20.
984.  945.  826.  816.  800.  783.  749.  714.  677.  658.  598.  556.  516.  456.  275.  78.  24.  20.  20.
20.
984.  947.  835.  800.  783.  767.  734.  701.  667.  650.  597.  560.  524.  471.  303.  96.  25.  20.  20.
20.
984.  947.  857.  777.  769.  758.  730.  699.  667.  649.  596.  560.  524.  471.  303.  99.  25.  20.  20.
20.
```

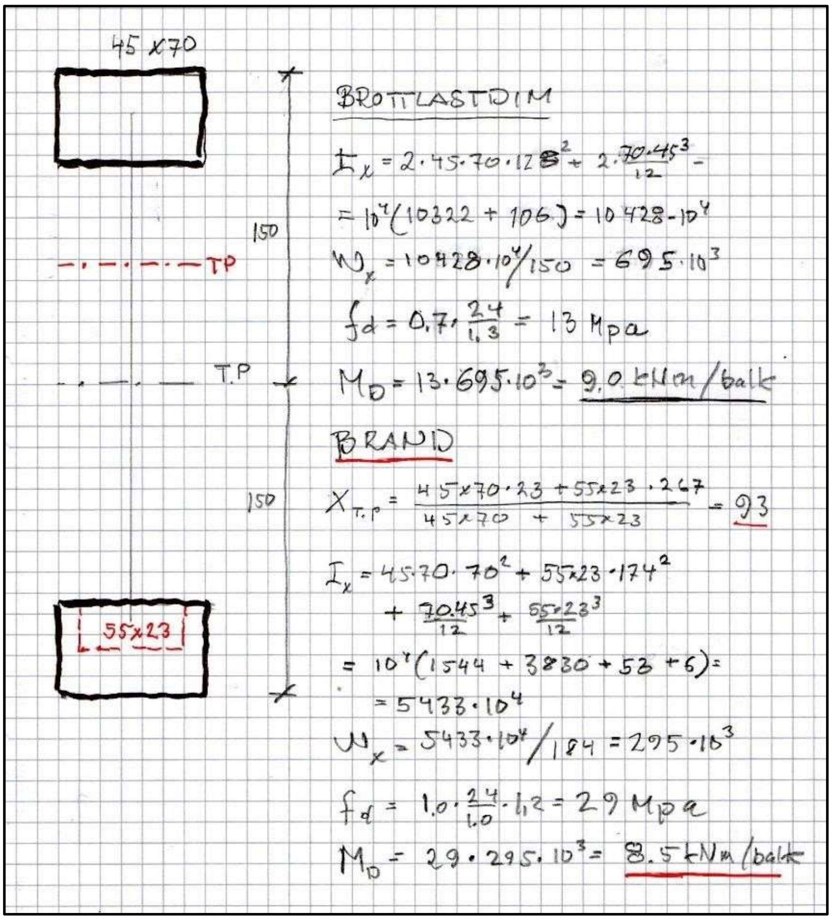
Figur 12

Using the temperatures in figure 12, the 200 degree isotherm has been constructed and superimposed over the rule cross-section in figure 13.



Figur 13

The effective cross-section after 90 minutes of standard fire exposure thus corresponds to an area of approx. 55 x 23 mm. Figure 14 shows an approximate calculation of what this may mean in terms of bearing capacity.



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$I_x = 2\cdot45\cdot70\cdot128^2 + 2\cdot\frac{70\cdot45^3}{12} =$

$= 10^4(10322 + 106) = 10428\cdot10^4$

$W_x = 10428\cdot10^4/150 = 695\cdot10^3$

$f_d = 0{,}7\cdot\frac{24}{1{,}3} = 13$ Mpa

$M_D = 13\cdot695\cdot10^3 = \underline{9{,}0\text{ kNm/balk}}$

BRAND

$X_{T.P} = \frac{45\times70\cdot23 + 55\times23\cdot267}{45\times70 + 55\times23} = \underline{93}$

$I_x = 45\cdot70\cdot70^2 + 55\times23\cdot174^2$
$+ \frac{70\cdot45^3}{12} + \frac{55\times23^3}{12}$
$= 10^4(1544 + 3830 + 53 + 6) =$
$= 5433\cdot10^4$

$W_x = 5433\cdot10^4/184 = 295\cdot10^3$

$f_d = 1{,}0\cdot\frac{24}{1{,}0}\cdot1{,}2 = 29$ Mpa

$M_D = 29\cdot295\cdot10^3 = \underline{8.5\text{ kNm/balk}}$

Figure 14

Calculated dimensioning bearing capacity for breaking load dimensioning is 9 kNm per beam, while calculated dimensioning bearing capacity in case of fire is 8.5 kNm per beam. Since the dimensioning load in the case of fire can be estimated to be of the order of 50% of the dimensioning load in the breaking load dimensioning, the fire load case is not dimensioning for the bearing capacity even at 90 minutes of standard fire impact (REI 90).

3.3 Flooring corresponding to section 3.2 with ventilation duct

The joist design is the same as in section 3.2, but a ventilation channel for exhaust air with a diameter of 125 mm is inserted between the upper and lower flanges of the Posi-Joist beam. Computationally, the round channel is approximated to a rectangular channel with the same area. The channel means that the construction is affected not only by fire from below, but also by the temperature in the channel corresponding to figure 5.

The channel is placed midway between the top and bottom fins. With a beam height of 300 mm, there is a space between the channel side and the upper and lower flange of 45 mm. A calculation of the temperatures with the assumption that these 45 mm spaces are filled with the loose wool insulation as described in section 1 shows that too large parts of the wooden flanges char away at 60 minutes of standard fire exposure. Therefore, the corresponding calculation is made, but with the condition that a heavy stone wool disc type soil disc or equivalent (density approx. 150 kg/m3) is placed between the duct and the lower or upper flange.

Selected node division for the TASEF calculation is shown in figure 15.

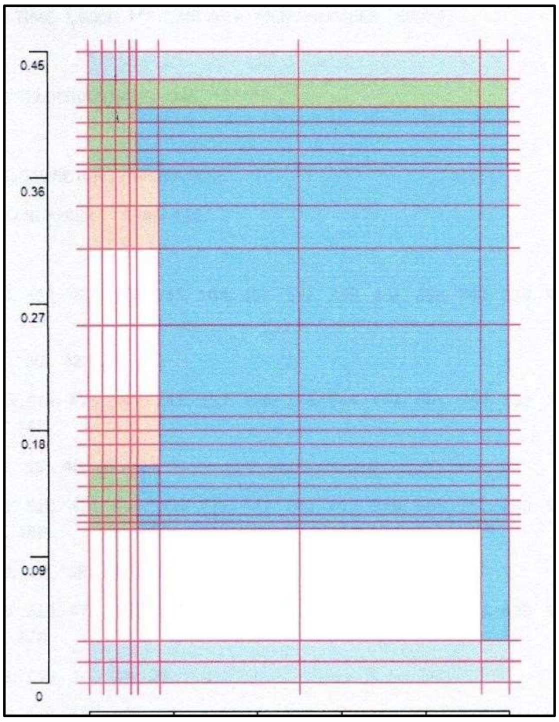


Figure 15

Figure 16 shows a temperature picture after 60 minutes of standard fire exposure.

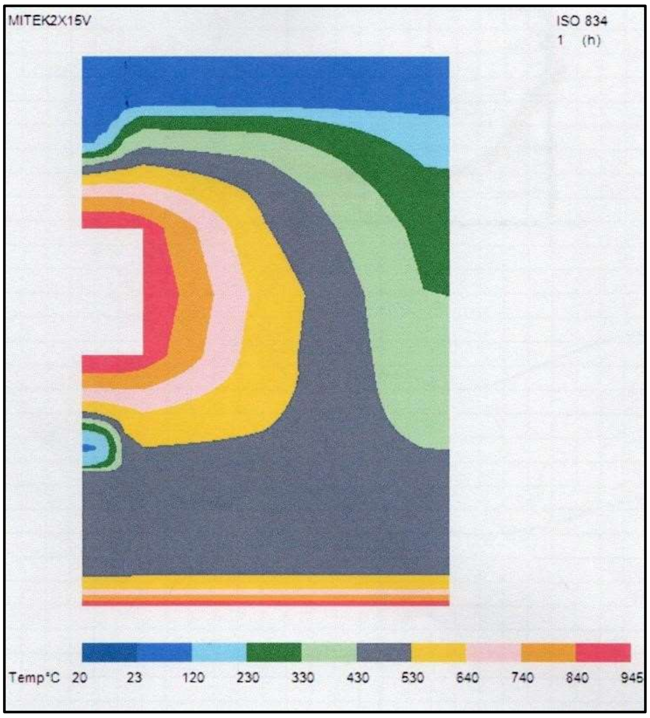
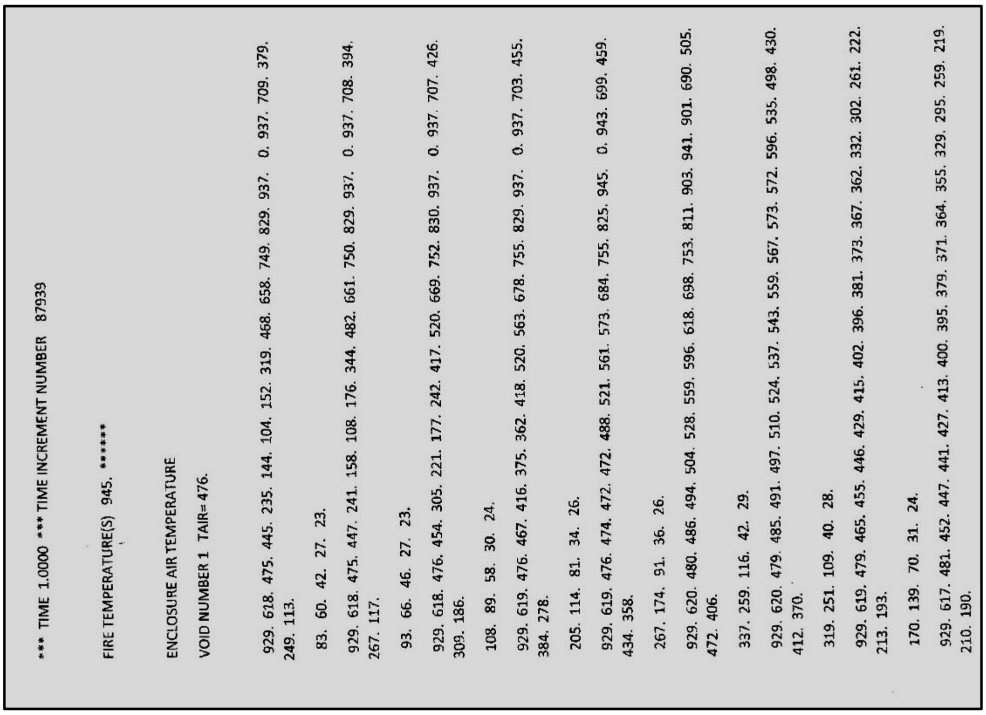


Figure 16

Figure 17 shows calculated temperatures in all node points after 60 minutes of standard fire exposure.



```
*** TIME 1.0000 *** TIME INCREMENT NUMBER   87939


FIRE TEMPERATURE(S)  945.  ******


ENCLOSURE AIR TEMPERATURE

VOID NUMBER 1   TAIR= 476.


 929. 618. 475. 445. 235. 144. 104. 152. 319. 468. 658. 749. 829. 937.   0. 937. 709. 379.
249. 113.

 83.  60.  42.  27.  23.

 929. 618. 475. 447. 241. 158. 108. 176. 344. 482. 661. 750. 829. 937.   0. 937. 708. 394.
267. 117.

 93.  66.  46.  27.  23.

 929. 618. 476. 454. 305. 221. 177. 242. 417. 520. 669. 752. 830. 937.   0. 937. 707. 426.
309. 186.

 108.  89.  58.  30.  24.

 929. 619. 476. 467. 416. 375. 362. 418. 520. 563. 678. 755. 829. 937.   0. 937. 703. 455.
384. 278.

 205. 114.  81.  34.  26.

 929. 619. 476. 474. 472. 472. 488. 521. 561. 573. 684. 755. 825. 945.   0. 943. 699. 459.
434. 358.

 267. 174.  91.  36.  26.

 929. 620. 480. 486. 494. 504. 528. 559. 596. 618. 698. 753. 811. 903. 941. 901. 690. 505.
472. 406.

 337. 259. 116.  42.  29.

 929. 620. 479. 485. 491. 497. 510. 524. 537. 543. 559. 567. 573. 572. 596. 535. 498. 430.
412. 370.

 319. 251. 109.  40.  28.

 929. 619. 479. 465. 455. 446. 429. 415. 402. 396. 381. 373. 367. 362. 332. 302. 261. 222.
213. 193.

 170. 139.  70.  31.  24.

 929. 617. 481. 452. 447. 441. 427. 413. 400. 395. 379. 371. 364. 355. 329. 295. 259. 219.
210. 190.
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Figure 17

Using the temperatures in figure 17, the 200 degree isotherm has been constructed and placed over the cross section of the lower and upper flange respectively. See figure 18.

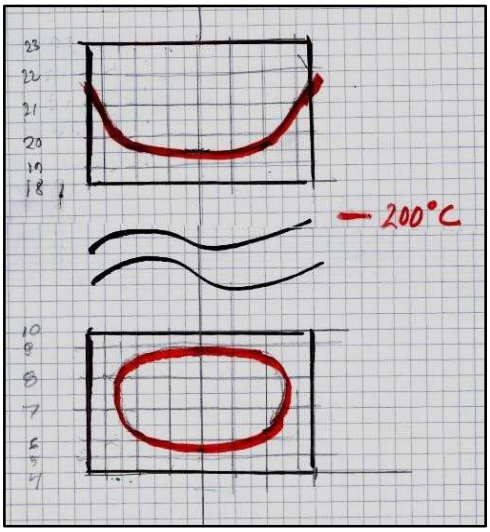

Figure 18

Through a comparison with the calculation of the bearing capacity according to Figure 14, it can be stated that the fire load drop does not become dimensioning for the beam's bearing capacity after 60 minutes of standard fire exposure. The solution with protection between the duct and the lower or upper flange with a 45 mm stone wool disc type ground disc or similar with a density of approx. 150 kg/m3 thus meets fire technical class REI 60. The discs are only needed as protection locally in the compartment where the exhaust air duct passes through a beam.

4 Summary results

A number of temperature calculations of the Posi-Joist joist have been carried out based on conditions according to EN 1995-1-2.

In summary, the following can be stated:

Joists **without** ventilation ducts for exhaust air built into the joists meet REI 60 with 2 x 15 fire gypsum board with a large margin. Fire-technical class REI 90 is also met.

Floors **with** ventilation ducts for exhaust air built into the floor meet REI 60 provided that a 45 mm thick ground board or equivalent with a density of approx. 150 kg/m3 is placed as protection between the duct and the upper and lower flange locally in the compartment where the duct passes a beam. See figure 19 a.

An alternative to the above is for the duct to be isolated locally where the duct passes through a beam with a 45 mm thick stone wool mesh mat intended for fire engineering insulation of ventilation ducts See figure 19 b.

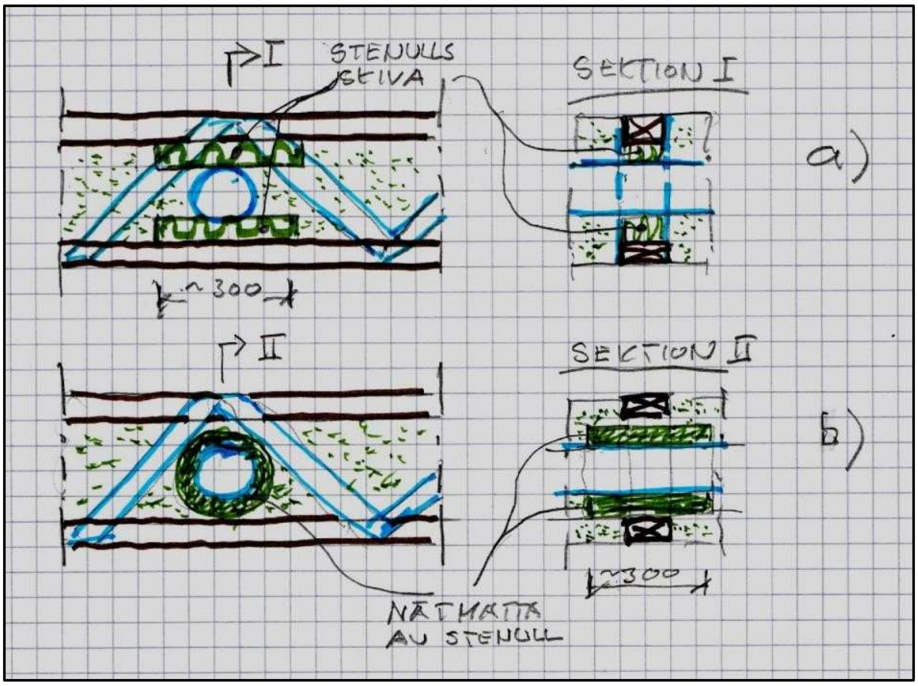

Figure 19

At sufficiently high beam heights, where a distance between the ventilation duct and the flange of the lower or upper flange of the beam of at least 120 mm occurs, loose wool is sufficient as protection between the ventilation duct and the flanges of the beam for fire-technical class REI 60.