The Development of Fireproof Construction in Brussels Between 1840–1870

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Fireproof mill construction had been developed in England at the end of the 18th century. In Brussels, the first large fireproof building was constructed in 1844–1847. All at once, the backlog of 50 years was eliminated. Moreover, for Brussels, the experimental period just started. Not bound by traditions, new techniques and materials were soon adopted. The evolution of the construction history of fireproof building in Brussels is discussed by going more deeply into the construction of six buildings, erected between 1844 and 1870.

INTRODUCTION
The construction of fireproof mills in England was thoroughly investigated between the 1970s and the 1990s.1 Mills have been surveyed, correspondence and files have been analysed. Sociologists, historians, archaeologists, architects and engineers have discussed the subject. As a result, knowledge can now only be extended by placing the subject in an international context.

BRUSSELS
In 1980, the Archives d’Architecture Moderne2 took the initiative to make up an urgent inventory in response to the neglect and the demolition of the industrial heritage. It contained a brief description and photographs of all the industrial buildings in Brussels erected before 1940. The inventory, consisting of 24 files and containing more than 1,300 industrial buildings, mentioned 42 multi-storey fireproof buildings, constructed between 1844 and 1913. The majority of these fireproof buildings were constructed after 1870. Only six were erected between 1844–1870. The six buildings constructed before 1870 are interesting since they reflect important steps in construction history: the replacement of cast-iron beams by rolled wrought iron ones and later riveted sections, the change from single vaults to secondary girders.

This paper examines the construction of these six early examples: a warehouse (1844–1847), a flour mill (1851), a crystal warehouse (1854), a pawnshop (1859–1863), a paper factory (1863) and a piano factory (1865–1870). These reflect the economic activity of 19th-century Brussels, which was known for the production of luxury goods. Next to warehouses, paper and piano factories, we come across chocolate factories, sugar refineries and breweries, all built to be fireproof. In these buildings, fireproof construction is not only used to assure fire safety. Load-bearing capacity and water-resistance were important as well. It will become clear that the improvement of fireproof building techniques was not dictated by the development of a particular industry. The improvements were more likely due to the architects who realised the constructions.

STORAGE WAREHOUSE (1844–1847)
The first public building in Brussels where cast iron was applied on a large scale was the warehouse at the inner harbour.3 This building was the result of a competition, organised by the town council in 1842. An earlier warehouse, situated on the Quai au Foin, had become too small. Architect Louis-Jacques-Charles Spaak4 (1803–1893) won the competition. Spaak studied architecture at the Académie des Beaux-Arts in Brussels and had worked in the studio of architect Lefuel in Paris. The public warehouse would become the masterpiece of his career.

The new warehouse was built on the Grand Bassin, a dock which had been excavated in 1830. The building was situated on the junction of the most important arteries, namely the railway station which connected north to south, the canal to Willebroek and the so-called coal canal to Charleroi, dug in 1832. King Leopold I laid the first stone of the warehouse in 1844 and the building was completed by 1847. When the inner docks were filled in, in 1910, the warehouse was demolished.5

It is clear that we are dealing with a construction that was considered standard at that time in England. The construction is not new, but shows that Brussels architects were well aware of English expertise. The structural analysis is based upon the original construction drawings, containing plan, section and ironwork details. The five-storey storage warehouse had a rectangular plan, measured 115m by 63m and was conceived around three covered inner courtyards. These courtyards were soon transformed into a railway station
to facilitate loading. The 34 stocks on ground level were destined for heavy goods. The first, second and third floors were divided into smaller spaces by brick walls, where traders could rent a room.

The ground floor was built up in brick vaults. The structural system of the upper floors consisted of brick arched floors, supported by asymmetric hog-back I-profiles. The cast-iron beams were simply supported over the columns and gave total depths of 40cm to the ends and 50cm at the centre. The bottom flange increased from 14cm at the support to 20cm at mid-span. The cross-section follows Hodgkinson’s practice. The cast-iron beams, 610cm long, ended in a half-circle. They were connected with two bolts. To take up the arch’s thrust of the vaults, spanning 375cm, tie bars were connected between the beams. Being concealed within the brick arch to protect them against fire, they became structurally inefficient. The fourth level was covered with a saddle roof with Polonceau trusses. No combustible materials were used in the construction.

There is no information available about the calculation of the structural elements of the public warehouse, but at that time, the beam formulae of Bage (1803) and Hodgkinson (1830) were theoretically available. If we recalculate the cast-iron beam according to the formula of Hodgkinson, the permissible point load which can be placed in the middle of the beam, comes to 158kN. When taking

Figure 1. Brussels warehouse (1844–1847). View from the Trade Dock in 1860 (Monteyne).

Figure 2. Brussels warehouse (1844–1847). Transverse section and typical floor plan, 1843 (AAM).
into account the non-linear elastic behaviour of cast-iron and using the German method of the virtual E-modulus, developed in 1990, to predict the load-bearing capacity of these cast-iron beams,\textsuperscript{8} we come to a permissible point load of 172kN, which is slightly higher. Since the beam carries a floor segment of 23m\textsuperscript{2}, this point load leads to a total distributed load of 15kN/m\textsuperscript{2}, or an imposed load of 7.5kN/m\textsuperscript{2} on top of the self-weight of the floor of 7.5kN/m\textsuperscript{2}.\textsuperscript{9} This is a typical load for storage.

The hollow cylindrical columns were connected by sliding one over another. The diameter of the columns decreased when going up. The original drawing shows a hollow cylindrical column with an outer diameter of about 27cm and a wall thickness of about 3.5cm. The free-standing height of the column is 345cm. This leads to a slenderness ratio $\lambda$ of 41. We recalculate the load-bearing capacity of the column with the formula of Hodgkinson (1840), written in metric units by the Frenchman Arthur Morin in 1862:\textsuperscript{10}

$$P = 106.76 \times (D^{3.6} - d^{3.6})/L^{1.7}$$

$P$ is the ultimate point load, expressed in kN,\textsuperscript{11} placed on an axially loaded column. $D$ and $d$ are respectively the outer and inner column diameter in cm. $L$ is the column height in dm(!). A safety factor of 6 was applied.

Hodgkinson’s formula overestimated the load-bearing capacity. The point load comes to 4,000kN, which is four times higher than the actual maximum load on the column, being 1,100kN. In England, the Rankine-Gordon formula is used to assess cast-iron columns.\textsuperscript{12} In Germany, the revised formula of Tetmajer is used.\textsuperscript{13} The latter formula gives a point load of 1,500kN, which reflects a proportional design of beams and columns.

**Flour Mill (1851)**

The oldest standing fireproof building in Brussels is the former flour mill, dating from 1851, situated at the Coal Quay, between the river the Senne and the canal to Charleroi.\textsuperscript{14} The Société Anonyme des moulins à vapeur de Bruxelles fabricated flour from wheat, rye, semolina, barley and starch, using a steam
Figure 4.
Flour mill (1851).

Figure 5.
Flour mill (1851).
engine. In 1960, the *Industrie Laitiaire Ardennaise* implemented a refrigeration system to fabricate milk products. Since 1979, the building has been used for office and storage. In 1999, a famous Belgian dancer converted the attic, with its timber trusses, into a spacious loft.

The construction of the building differs from the standard fireproof construction, since the usual brick barrel vaults are replaced by cross vaults, each supported by four cast-iron beams. Even in England, this construction was exceptional. On the one hand, the double curvature of the vault complicates the false work and brick laying and increases the quantity of cast iron needed. On the other hand, the self-weight of the floor decreases and the load-bearing capacity increases. The end arch thrusts are divided into two directions, causing the horizontal forces on the outer walls to reduce.

The four-storey mill has a rectangular plan of 24m by 14m. The inner space is divided by two rows of eight columns. The position of the cast-iron columns is irregular and leads to various beam lengths, which complicate the production. The distance between the columns varies from 200cm to 460cm. The irregular partition inside can be derived from the outer façade. The abutments that support the cast-iron beams are clearly visible.

In one bay, where the brick arch had been replaced by a concrete plate, the shape of the beam becomes visible. The parabolic web profile gives depths of 19cm at the support to 27cm at the centre. At mid-span, the bottom flange in tension (18cm) is twice as wide as the upper flange in compression (9cm), leading to a ratio bottom flange area to top flange area of 4 to 1. Since four beams meet at one column, the cast-iron beam ends in a quarter of a circle. Each beam is connected to the column with two bolts.

Although the dimensions of the individual beams are rather small, the load-bearing capacity of the floor is high, due to the double number of beams used. The cast-iron beam, 460cm long, calculated according to the German method, can carry a total load of 19.28kN/m², which leads to an imposed load of 11.78 kN/m², next to the self-weight of the floor of 6kN/m². This is very high, even for a flour mill. The columns are designed as such. The diameter of the hollow cast-iron column, 280cm high, decreases from 20cm on the first floor to 16cm on the fourth floor.

Figure 6. Flour mill (1851). Four cast-iron hog-back I-beams carry the cross vault; one floor segment has been replaced by a concrete slab, 1999.
The oldest standing partially standard fireproof building is the former crystal warehouse Val Saint-Lambert at the Vieux Marché aux Grains in the centre of Brussels. To reach the warehouses one has to pass the gate in the mansion. Until 1970, the mansion housed the showroom and offices from the crystal business. The crystal vases, glasses and other objects were stocked in the two warehouses. Only the ground floors of the three storey high warehouses are built fireproof. On the second and third level, cast-iron columns carry a wooden floor. The wooden beams and girders are protected with a lath-and-plaster ceiling.

The two warehouses are built up according to an orthogonal grid. The outer walls follow the irregular border plot. The two rows of five columns in the first warehouse are placed on a grid of 420cm by 460cm. The cast-iron beams, which span 460cm, are perpendicular to the walls, allowing light to penetrate. In the second warehouse, the inner space is divided by three rows of six columns. The cast-iron beams span 420cm. The wide of the vault is adapted to the former activity and varies between 440cm and 300cm. The total construction height of the fireproof floor measures 64cm. The brick flat arch (f/l = 11) is 1 stone high in the middle (18cm) and 1½ stone high at the supports. The arch is filled in with sand and bricks and covered with tiles.

The cast-iron beam ends in a half-circle and is connected with a bolt to the other beam. The depth of the asymmetric I-beam increases from 30cm at the column to 40cm at mid-span. The bottom flange is parabolic in plan.

Figure 7. Crystal warehouse (1854). Plan and section.
and broadens from 11 to 14cm. At mid-span, the bottom flange is four times larger than the top flange. Due to the heavy weight of the floor (7.5kN/m²), the total permissible load of 9.63kN/m² leads to an imposed load of 2.48kN/m². This load is in line with the original function of storage of hollow and therefore light objects. Since 1998, the building has been adapted as a cultural centre and this function implies a higher imposed load. Material tests on the cast-iron beam revealed that the cast iron is of high quality and that a permissible tensile stress of 72N/mm² can be taken into account. The imposed load comes then to 4kN/m², which is standard for such a purpose.

In each bay, three ties are provided: one in the centre of the beam, the other two pass trough the columns. A thrust beam is worked into the outer wall. The freestanding height of the inner space reduces when going up: 355cm on ground level, 324cm on the second and 306cm on the third. Although the load and the height of the column increase from the third to the first floor and, as a consequence, the risk to buckle, the outer column diameter is 20cm on all levels. Resistance against buckling can also be obtained by increasing the wall thickness. The inner diameter of the ground floor column comes to 15cm, but, due to great eccentricity, the wall diameter varies from 1.9cm to 3.1cm. The maximum load on the column after adaptive reuse is 445kN. The revised formula of Tetmajer predicts a load-bearing capacity of 580kN, if the column were perfectly symmetrical. Recalculating the column with a wall thickness of 1.9cm leads to a capacity of 475kN. So, in this case the engineering is easy, since the latter can still stand the maximum load. The following test, carried out in 1988, shows that there is a difference between theory and practice. The column described above had been tested to determine fire resistance. The column had been protected with a 10mm thick sprayed coating, loaded with a point load of 700kN and exposed to the ISO-fire curve. In fact, loading this cast-iron column with 700kN was not evident in the light of the calculation, but it resisted the fire test even for 110 minutes. At that moment, the temperature in the column was near 800°C. Given that the overall strength of cast iron drops beneath 20% at 800°C, the real capacity of the column was much higher than the calculated value.

These three buildings are the only Brussels industrial buildings of medium height where
cast-iron is used in columns as well as in beams. From then on, wrought iron takes over from cast-iron beams.

**Pawnshop (1859–1863)**

The construction of the pawnshop is innovative in several respects. Wrought iron is used, primary as well as secondary beams are applied and the cast-iron columns are clad to increase their resistance to fire.

In 1859 the architect Alexis Partoës (1820–1887) was invited to build a new pawnshop in the Saint-Ghislainstreet in Brussels. Partoës just had finished his studies at the École Polytechnique in Paris. Although we are not informed about the requirements of the investor, one can expect that in a pawnshop a maximum of stock was required in a building which could resist fire and burglary. To reduce building costs, the height of the elevations was minimised. The floor-to-floor height measures only 255cm. The wide jack arch spanning between primary beams gave way to smaller arches spanning between secondary beams, which themselves were supported by the primary beams. This system efficiently reduced the thickness of the floor to 26cm and, hence, could halve the self-weight to 3,5kN/m². Wrought iron was used for primary beams as well as for secondary girders. The main beam, spanning 420cm, is shaped as a double I-profile. The wrought-iron girders, spanning 440cm, have the shape of a symmetrical I-profile and are bolted to the main beam. The brick vaults span 84cm. In the end bay, three ties are provided and in the other bays two.

In this way, a construction grid of 420cm by 440cm was created. This construction module was logically combined to an L-shaped layout with two rows of cast-iron columns. On the ground floor, the public functions are located: the counters and the
salesroom. The four storeys and the attic are destined to stock the pawn goods (silverware, furniture, jewellery, bikes, art objects, etc.). The difference in height of the site is bridged at ground level to give the public counter room a monumental height and to allow the structural elements on the four storeys to be analogous. The primary beam is shaped in a double I and measures 26cm high and 8cm wide. The girders are 15.5cm high and 6.5cm wide. The girder is connected to the beam with an L-profile attached with three bolts on each web. The beams run from column to column. A connecting-piece is applied to connect the cast-iron columns and to connect the two beams and two girders who meet at this point. The cast-iron columns are solid. The diameter increases from 6cm on the top level to 14cm on the ground floor. The roof has Polonceau trusses.

From 1840 onwards, scientists argued about the fire resistance of cast iron. Should it or should it not be protected? In this building, it was decided to protect the metal structure. The girders are built in between the brick vaults and covered with plaster. The cast-iron columns are enveloped with a 9cm thick layer of natural stone. And, of course, wood is excluded: stairs, windows and even the gutters are in metal.

Other isolated examples (e.g. a sugar refinery of 1885 with clad column heads and beams) clarify that there was no unambiguous regulation or recommendation about the fire resistance of cast-iron structures in Brussels. As in England and America, it would take a while before scientists realised that one had to make a difference between the ‘resistance to fire’ of a material and the ‘reaction by fire’.

Today, this remarkable building still acts as a pawnshop, the last one in Belgium. In 1998–2002, it was thoroughly renovated and the floor of the third level has been removed to enlarge the height to accommodate new stock.

When recalculating the structure of this building, many questions arise. If we take into account a tensile stress of 77N/mm² for wrought iron, the admissible point load in
the middle of the primary and secondary beam is respectively 67.8kN and 87.0kN. The load on the floor is then restricted by the capacity of the primary beam to 4.9kN/m². When not taking into account the load factor used by the EC,22 there is only 1.4kN/m² available for stocking the goods, since the self-weight of the floor comes to 3.5kN/m². Taking into account the position of the shelves and the relatively light weight of the stocked goods, this capacity is small but not unrealistic. Nevertheless, if we accept that the structure has not been overloaded in the past, there is still a safety problem. If one floor segment were to fail and fall down, the underlying floor could not stand the debris and would progressively collapse.

More surprising are the extreme slender columns on the ground floor. The 14cm thick solid cast-iron column leads, with a height of 560cm, to a slenderness ratio $\lambda$ of 160. Since the formula of Tetmajer is not valid for high slenderness ratios we use the formula of Euler to predict the capacity. With a safety coefficient of six, the load-bearing capacity comes to 100kN. The weight of the five floors above comes to a point load of 328kN or 453kN loaded. So, one can ask why this column can stand the load. Is the cast iron of an extreme high quality? This is doubtful, since solid elements lead to poor castings.23 Does the stone fire protection work structurally? There is a gap of one centimetre between the stone covering and the shaft of the cast-iron column. So, the stiffness of the column is not increased. Is the two-hinged model correct? Calculating the column with two fixed endpoints leads to a point load of 401kN. In reality the behaviour of the column is somewhere in between a hinge and a fixed point. Therefore, only a combination of positive aspects can explain the present resistance of the column. One thing is certain: if the column stands the load under normal conditions, it will certainly stand under fire conditions. A computer simulation points out that, due to the stone protection and the massive nature of the column, the temperature is not higher than 250°C degrees, even after two hours of fire exposure.24

Paper Factory (1863)
For the sake of completeness, the construction of the paper factory is discussed briefly. Little is now visible of the original structure,
which has been converted into a design furniture shop, but it was originally erected in 1863 as a paper factory, alongside the river Senne. The rectangular inner space, 33m deep and 18m wide, was divided by 13 rows of three columns. The ground floor is build up in single brick vaults. The floors on the second and third level are in timber. Cast-iron beams carry the floors on all levels. Later, the building started to bend towards the river and the cast-iron columns were enrobed with concrete. The movements have been stabilised. The original saddle roof has been replaced by an iron truss. On the ground floor, the flat brick arch (f/l = 10) spans 2.3m. The arch is 1.5 stones high at the supports and 1 stone high in the middle. The beam spans 4.4m and consists of two wrought iron I-beams placed one above the other. The I-beams (web 6.5cm and 21.5 high) are connected to each other by means of a plate, which is riveted into the flange of the beams. The tie-bars are connected in the upper beam. The shape of the beam is visible, because the end-bay has been removed over the total width of the building. This structural alteration was carried out in a careless manner. No measures have been undertaken to take up the end-thrust in the last bay. When the arch started sagging, the end columns were strutted against the wall.

**Piano Factory (1865–1870)**

The former piano factory ‘Berden et Cie’ has an iron-framed interior and concrete floor arches. The main beams are composed of riveted profiles.

The *Inventaire Visuel de l’Architecture Industrielle à Bruxelles* mentions that the building was erected between 1865 and 1870. In 1903 the building was bought by the quality chocolate shop Antoine and in 2000 was converted into loft space.

Originally the building had four levels. The inner space, measuring 10m by 30m, is structured by five cast-iron columns. The structural grid measures 500cm by 500cm, which is a relative large span in two directions. The beams that span from column to column are built up by two U-sections, riveted between two plates. The so-formed riveted beam is 24cm wide and 36cm high. An L-section is riveted to the web of the beam as support for the secondary I-profiles. Taking in account the date and the form of the beams, they might be in wrought iron or...
From a structural point of view, the uncertainty about the applied material is not a problem, since the load-bearing capacity of the floor is satisfactory. If we take into account a permissible tensile stress of 77N/mm² for wrought iron, the load-bearing capacity of the floor comes to 5.8kN/m². This is not much, but the lightweight concrete floor of 2.4kN/m² allows an imposed load of 3.4kN/m², which is enough to house a loft (2kN/m²). If it points out that the beams are in mild steel, the load-bearing capacity of the floor increases to 7.5kN/m² or an imposed load of 5.1kN/m² which leads to a wide range of possible reuses. The capacity of the hollow cast-iron columns does not bring us closer to the answer. They are over-dimensioned. The diameter of the columns goes from 23cm on the upper level to 25cm on the second, 27cm on the first and finally 30cm on ground level. The height varies between 2.20m and 4.20m, leading to a slenderness ratio $\lambda$ between 28 and 44. The point load on the ground floor column, 4.20m high and 30cm thick, comes to 850kN, which is far below the capacity of 1,495kN predicted by Tetmajer. So, even for the highest imposed load, they are not even 60% loaded.

The vaults, with a span of 71cm, are built up in un-reinforced concrete. The form of the arch differs from a brick arch. To minimise the quantity of concrete, the concrete arch is 9cm high in the middle, broadens to 14cm at the support and then goes straight down and touches the flange. The self-weight comes to 2.4kN/m². The height still measures 40cm. Although it seems an intelligent solution to construct lightweight arches, it is the only known example in Brussels. Future buildings were constructed again with bricks. In contrast to England and America, hollow pots were not used.
CONCLUSION

In Brussels, knowledge of fireproof construction was integrally adopted in 1840, but few buildings were erected until 1870. The first public building served as an example for private investors who constructed their own modest factories. This system of construction was appreciated for its fire safety, its load-bearing capacity and its resistance to water. Apparently, the protection of exposed iron was not obliged. When the fire risk was high, or the stocked goods valuable, the iron structure was protected with stone or plaster.

Brussels architects kept a close watch on international developments. They designed the cast-iron beams between 1840–1860 according to the prescription of Hodgkinson: asymmetrical I-beams with parabolic web and bottom flanges and a bottom-to-top flange area ratio of 4 to 1. Connecting rings were not applied. Only bolts were used. Columns were cylindrical, mostly hollow.

The design of columns and beams was not yet completely understood. The load-bearing capacity was restricted by the size of the main beams. The columns were, proportionately to the beams, over-dimensioned.

By 1860, cast-iron beams were replaced by wrought iron and later by riveted sections. Secondary girders were introduced.

Most of Brussels’ fireproof factories have lost their original function and have been transformed into offices, cultural spaces, lofts or shops, adaptations facilitated by their rectangular grid and structure. The moderate size and central location in the city centre of Brussels makes these buildings attractive.

Figure 14.
Piano factory (1865–1870). Recently converted into loft (Photograph J.P. Gabriel).
NOTES AND REFERENCES


2. The AAM was founded in 1968 by architects and historians. One of their goals is to value the building heritage, and to collect and preserve documents that are essential for the Belgian modern architecture.

3. The Journal d’Architecture wrote in April 1848: ‘C’est le premier de nos grands édifices publics où la fonte ait été employée sur une aussi grande échelle et d’une manière aussi générale, comme supports et appui de voûtes.’

4. From 1830 to 1867 Louis Spaak was the architect of the Brabant region. He built more than 50 schools and local government offices. The ‘Brussels warehouse’ was his best architectural project.


6. Fitzgerald, ref. 1, 135.

7. The permissible point load is calculated by dividing the break point load by 2.5.


9. The cast-iron beam was calculated taking into account a permissible tensile stress of 52N/mm². Although the London Act advised a value of 23N/mm², this is a realistic value, since Bage and Hodgkinson used values between 56 and 62N/mm². When calculating according to the Eurocodes, the load factors of 1.35 for self-weight and 1.5 for imposed load have to be added which result in a permissible imposed load of 3.24kN/m². (Q_{total} = 1.35 \cdot G_{self-weight} + 1.5 \cdot Q_{imposed})

10. Morin, A., Résistance des matériaux (Paris: L. Hachette et Cie, 3rd edn, 1862), 188. Arthur Morin (1795–1880) studied at the Ecole Polytechnique and took up a military career. He was director of the Conservatoire des Arts et Métiers, corresponding member of the Société Industrielle de Mulhouse and of the Manchester Literary and Philosophical Society.

11. In the original formula kg was used instead of kN (100 kg = 1kN).


13. König, B., Historische Gusseiserne Stützen — Ein Zerstörungsfreies Beurteilungsverfahren für die Belastbarkeit bei Normaltemperatur und im Brandfall (Wupperal: Bergische Universität GH, 1995). The original formula of Tetmajer to calculate the load-bearing capacity of a column in cast-iron takes into account a mean compression strength of 776N/mm². König revised the formula in 1995 for a mean compression strength of 600N/mm². This leads to the following formula P = A(0.0215 \lambda^2 − 7.29 \lambda + 600).


According to the Eurocodes this results in a permissible imposed load of 7.45kN/m\(^2\) since \(Q_{\text{total}} = 19.28kN/m^2 = 1.35 \times 6kN/m^2 + 1.5 \times 1.35 \times 7.45kN/m^2\).

The use of light timber floors on the second and third level reduces the dead load on the columns.

Oriëntatieproef betreffende de weerstand tegen brand van een kolom. Proefverslag nr.5917. (Gent: Laboratorium voor aanwending der brandstoffen en warmteoverdracht, 1988)


When we do bring the load factor of EC5 into account the imposed load is restricted to 0.1kN/m\(^2\), which means that nobody can enter the building.

\[ Q_{\text{total}} = 1.35 \times G_{\text{self-weight}} + 1.5 \times Q_{\text{imposed}} = 1.35 \times 3.5kN/m^2 + 1.5 \times 0.1kN/m^2. \]


The fire compartment had been modelled using the computer programme Ozone v.2.1.5. (2001) which has been developed at the Université de Liège in Belgium in the context of the ECCS research project about ‘Natural Fire Safety Concept’.

The owner of the building did not give permission to carry out any material tests.

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