SCHOONDERBEEK EN PARTNERS ADVIES BV

THE ENVIRONMENT, NOISE, BUILDING CONSULTANCY SERVICES, FIRE SAFETY, SPATIAL PLANNING, POLICY CONSULTANCY SERVICES

20110645.R02b

Retaining walls with Legioblock concrete blocks
Investigation into fire resistance with a roof construction

Date: 16 February 2012

2. INTRODUCTION

A. Jansen Beton BV supplies concrete blocks referred to as 'Legioblock'. The Legioblocks are stacked to produce fire-resisting retaining walls for storing combustible materials such as timber, rubber and PVC. Since legislation and regulations in the area of fire safety must be met, an investigation was performed. This report provides details of said investigation. The investigation mainly refers to situations with a roof construction.

3. PRINCIPLES AND SCOPE

The concrete blocks are made of grade C25/30 concrete (no reinforcement) and their dimensions (length x width x height) are 1.6 m x 0.8 m x 0.8 m or 1.6 m x 0.8 m x 0.4 m with the related accessories. The concrete blocks are stacked on top of each other using studs and holes that fit together. The blocks have chamfered edges that measure 10 mm. The thickness of the retaining wall measures 0.8 m.

The concrete Legioblocks are incombustible and fall within the scope of the highest A1 class in accordance with the DIN EN 13501-1 standard. The investigation is only related to the Legioblock retaining walls with the features and properties described for this.

The investigation is based on the provided data and applicable standards, in particular:

- The standard: DIN EN 13501-1:2007 Klassifizierung von Bauprodukten und Bauarten zu ihrem Brandverhalten - Teil 1: Klassifizierung mit den Ergebnissen aus den Prüfungen zum Brandverhalten von Bauprodukten (Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests; + Blatt A1 2009; Sheet A1 2009);
- The standard: DIN EN 13501-2:2008 Klassifizierung von Bauprodukten und Bauarten zu ihrem Brandverhalten; Klassifizierung mit den Ergebnissen aus den Feuerwiderstandsprüfungen (Fire classification of construction products and building elements - Part 2: Classification using data from fire resistance tests, excluding ventilation services; + Blatt A1 Entwurf 2007; Sheet A1 Layout 2007);
- DIN EN 1363-1 Einheitstemperaturzeitkurve (Standard fire curve);
- Eurocode 2 Teil 1-2 (EN 1992-1-2) Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken – Teil 1-2 Allgemeine Regeln – Tragwerksbemessung für den Brandfall (Design of concrete structures – Part 1-2: General rules – Structural fire design);
- Fire Recyclinghof Essen, 26 January 2011;
- Fire Kost Bochum, 16 July 2007.

The principles have been explained by the customer.

The most important objective with regard to the classification in storage sections separated by concrete retaining walls is to prevent fire propagation. This mainly applies to fire propagation towards the adjacent premises of third parties but also the adjacent storage sections and buildings on the organisation's own business site. In addition, health and environmental risks play a role as does the risk involved in fighting fire.

The present investigation is related to the following application area:

- Combustible materials such as timber, rubber and PVC. No combustible materials with a specific energy higher than 35 MJ/kg. No liquid fuels or explosion hazardous materials.
- Retaining walls up to a height of 6 metres.
- Retaining walls up to a height of 8.8 metres with combustible storage material up to 1.6 metres below the level of the retaining wall.
- Retaining walls higher than 6 metres where the vertical gap openings between the Legioblocks (insofar as they are wider than 5 mm) are sealed to be fire-resistant.
- The roof construction is made of incombustible material.
- An appropriate structural stability of the retaining wall in accordance with the EN 1990 and EN 1991-1 standards.

4. FIRE RESISTANCE ANALYSIS

A link with current standards such as the DIN EN 13501-2 standard has been sought as much as possible when assessing the fire resistance of the Legioblock retaining walls. The fire resistance is expressed in minutes where the criteria for Tragfähigkeid (R; Load-bearing capacity), Raumabschluss (E; Integrity) and Wärmedämmung (I; Thermal insulation) have to be met. The REI120 classification, for example, represents a structure that will meet these three criteria for 120 minutes. The fire resistance of a retaining wall is determined by the following:

- The temperature behaviour and heat radiation on the cold side of the wall (§ 3.1).
- Spalling: decay of the concrete surface because of heat (§ 3.2).
- Fire-tightness.
- Open seams between the concrete blocks.
- Structural aspects: the wall may not collapse.

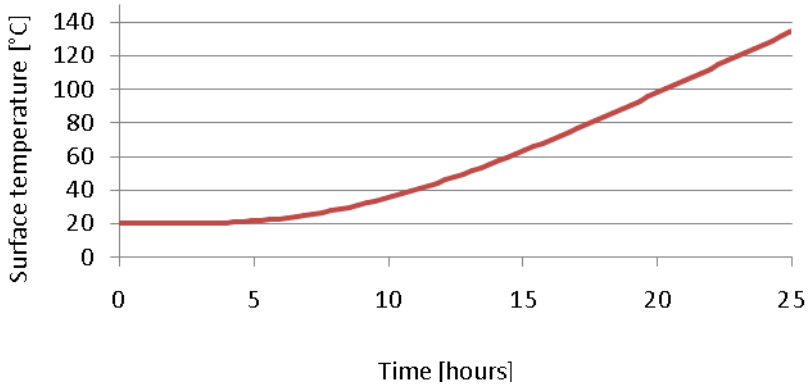
4.1. Temperature behaviour and heat radiation

Calculations have been made with regard to the temperature distribution in the concrete based on the DIN EN 13501-2:2008 standard regarding the fire resistance of concrete. The retaining wall has been represented schematically as a solid concrete wall with a temperature of 1200 ℃ on the fire side. Temperature calcu lations have been made using the finite element method. The following principles were used when making the calculations:

- Heat conductivity coefficient of the concrete: 2.0 W/mK
- Specific heat: 840 J/kgK
- Contact resistance on the fire side: 0 m^2K/W
- Contact resistance on the protected side: 0.20 m^2K/W

The calculated temperature behaviour is shown in Figure 1. It shows that the calculated surface temperature on the other side is less than 22 ℃ after 4 hours. The radiation heat is, therefore, less than 1 kW/m^2.

Figure 1
Surface temperature during a 1200 ˚C fire



4.2. Concrete decay: 'spalling'

An internal pressure is created when concrete is heated quickly because the moisture present is converted into steam in a short period of time of which the volume increases considerably and quickly and the external layer can be compressed. This is referred to as 'spalling'.

Spalling has been taken into account when dimensioning concrete structures based on current structural standards such as Eurocode 2. The spalling is factored into a reduced residual cross section of the concrete wall. It must be concluded that the decay (‘spalling’) of the non-reinforced concrete blocks is limited to the surface and does not have a considerable impact on fire resistance based on Eurocode 2 regarding the fire resistance of concrete. It has also been observed that the spalling was limited to the corners of the concrete blocks in outdoor fires that have occurred during the last few years. This decay does not affect fire-resisting performance and the Legioblock retaining wall will remain erect during a fire for at least 4 hours.

4.3. Seams/gaps

The blocks are stacked on top of each other using studs and holes that fit into each other. Despite careful stacking, gap openings between the stacked blocks are unavoidable both horizontally and vertically.

4.3.1. Horizontal gaps

The horizontal gaps between the blocks stacked on top of each other can be a few millimetres wide. The gap widths specified here are related to the net (aerodynamic) passage opening of the gap. It can be concluded that flashover does not occur based on the dimensions (height and width) of the gaps.

4.3.2. Vertical gaps

The dimensions of the vertical gaps between the blocks placed next to each other are related to the flatness of the substrate and are often limited to a few millimetres. A single exceptionally wide gap may be unavoidable locally up to a width of 30 mm. Flashover through the gap could be possible without the sealing facilities.

The following situations have been identified for the sealing of the vertical gaps between the Legioblocks:

- Situation 1: Between the retaining wall and the roof construction there is an opening that has a height of at least 1 m (around the whole of the storage). Sealing facilities are not required here because the hot flue gases can escape.
- Situation 2: One side is completely open (at least 20% of the circumference of the storage) up to the level of the highest point of the roof construction. The vertical gaps that are at a greater height than 2/3 of the average space are sealed (if combustible material can be found at this gap) insofar as they are wider than 5 mm.
- Situation 3: (Other situations): The vertical gaps that can be found at a height that is greater than 1 metre above floor level are sealed insofar as they are wider than 5 mm.

The sealing of the gaps can be achieved by using rock wool. Grout or other fire-resisting sealing materials can also be used.

The probability that there will be fire movement through the remaining vertical gaps has been further considered below. Heat radiation, air movements and air pressure differences as a result of fire have been taken into account.

Heat radiation
The gap can offer a 'view' of the seat of a fire from the compartment to be protected. A 30 mm gap offers a view factor of at most 0.02. Based on a seat of a fire with a radiation intensity of 100 kW/m^2, the radiation intensity on the receiving side will be 0.02 x 100 = 2 kW/m^2. This radiation intensity is so slight that flashover is excluded.

Air movements
The roof construction is generally realised with a steel structure without special fire-resisting properties. The situation where the roof construction has not (yet) collapsed is the benchmark. Pressure differences occur in the room exposed to fire in this situation: there is an underpressure at the bottom of the room exposed to fire while there is overpressure at the top. The movements of hot flue gases and flames through an open gap at the top of the storage space are determined by the overpressure as a result of the fire.

Situation 2; this overpressure is limited favourably by the unimpeded outflow of hot flue gases through the open side of the storage space. The conservative assumption has been made that an overpressure can occur in the top 1/3 of the space height and that these vertical gap openings will be sealed.

Situation 3; the outflow of hot flue gases is impeded in this situation. This can cause overpressure at the top of the space. The conservative assumption has been made that this overpressure can occur as from 1 metre above floor level. The vertical gap openings above this level must, therefore, be sealed.

The combustible flue gases and flames cannot penetrate to the other side of the retaining wall at the bottom of the storage space. Hot smoke can only reach the other side of the retaining wall under extreme theoretical conditions (a storm exactly perpendicular to the retaining wall or a narrow stack of material immediately against the retaining wall). Flames do not penetrate through the gap to the other side of the retaining wall.

4.4. Other fire resistance aspects

The fire resistance of building structures is generally determined based on fire tests, for example, in accordance with the DIN EN 13501-2:2008 standard. The present storage situations are essentially more favourable than the standard situation:

- The lapse of time of the local thermal load of the retaining wall is less favourable than the ‘standard’ fire curve from these standards.
- The room exposed to fire has an overpressure during the fire test. In the present situation, the room exposed to fire has an underpressure for the most part (there can be a slight overpressure at the top) as a result of the thermally driven air movements.
- Cotton buds are used to assess the fire resistance (fire-tightness) during the fire test. These cotton buds combust shortly after being exposed to heat. The present materials combust less easily as a result of the higher heat capacity, specific mass and chemical composition.

The relevant literature mentions the release of oil when rubber burns. Should this be the case at all, it would involve a small quantity. Oil and fire-extinguishing water can seep

through to the other side of the retaining wall. The oil will be cooled down and there is no source of ignition so that flashover cannot occur.

The structural stability of the retaining wall is important. The structure of the retaining walls is generally dimensioned based on the worst case scenario where storage material is present on one side with a large safety margin. The load combination during a fire (and possibly a strong wind) does not form a factor of any significance. The retaining wall will, therefore, not collapse should there be a fire.

The favourable behaviour during a fire has been confirmed based on fires that have occurred during the past years.

5. CONCLUSION REGARDING FIRE RESISTANCE

Insight has been obtained into the fire-resisting properties of Legioblock concrete retaining walls as partitions for the storage of combustible materials in roof construction situations based on the investigation. It can be concluded based on the investigation that the retaining walls have fire-resisting properties at the level of the REI 120 classification. This applies under the application conditions described in Section 2.

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