liability for damage, were driving forces in this process. It ultimately led to European standards for masonry, which greatly influence the current possibilities for brickwork.

The European pursuit of an open market has generally led to restrictions with regard to the creative and innovative application of brickwork façades. In contrast, the brick industry in particular has certainly been very active in recent decades. Numerous new products and systems have been developed. The mutual influence of practice and regulations is noteworthy in this respect. The innovations in construction industry are sometimes what leads to amendment of the regulations and contrary 'general aims' (such as the reduction of the use of fossil fuels) also often lead to increasing restrictive regulations and, therefore, force the building industry to come up with innovations. A notable moment in the timeline was the introduction of the insulated cavity wall at the beginning of the 1970s. Furthermore, it is striking that it lasted until late in the 20th century before the problem of cracks in the outer leaf of insulated cavity walls was handled with the implementation of guidelines and regulations for the provision of expansion joints in brickwork façades. In the mutual influence of practice and regulations the active role of the brick industry in the Netherlands, the BRIK programme and *'Mooi is gemetseld in baksteen'* (Beauty is masoned in Brick) promotional campaign are noteworthy in the 1980s.

The timeline not only appear to be a comprehensive overview, it can also inform future changes. Standards and regulations often impose restrictions, and conversely new developments and general aims also result in the amendment of legislation and regulations. Looked at this way, it can be expected that in the coming years energy and environmental aims will remain to play a prominent role in the development of standards and regulations. Furthermore the building industry will no longer be able to ignore the integration of European markets and the European standards and certifications will have a decisive influence on future standardisation of brickwork construction.

HISTORICAL PERSPECTIVE 1901–2015

GOVERNMENTAL REGULATIONS / NORMS INDUSTRY-DRIVEN REGULATIONS

1901

On the basis of the 'Act of 22 June 1901 (Bulletin of Acts and Decrees no. 158), providing for legal provisions governing the public housing' (which it should be noted only came into force on 1 August 1902) municipalities were charged with drawing up regulations and requirements to be demanded for dwellings. In this way, the Model Building Regulations arose on which municipalities based the local building regulations. The use of cavity walls was, in some cases, set forth in these building regulations, although this did not occured as prescribed at the beginning of the last century.

This example is from the Municipal Building Regulations of the city of Rosmalen, in which there is mention of sleeping rooms against external walls if these are treated as cavity walls.

[Art. 28] All walls of buildings, which contain working or residential spaces or other accommodation for people on the ground floor, must be supplied with a brick damp course (hard bricks in strong trass or cement mortar) at least 0.50 m high, in such manner that one half of it ends up beneath, and the other half above, the ground floor.

[Art. 33] The thickness of the walls of buildings are set out, whereby the thickness of load-bearing walls be at least 0.18 m thick.

[Art. 34] The thicknesses of the walls may not be adjusted to the required thickness by separate cladding in bricks (not bound into the wall), in whatever way, nor may be weakened by fitting recesses.

TECHNOLOGY AND CONSTRUCTION METHODS MATERIALS AND APPLICATIONS

Up until 1900 walls were made of solid brickwork, based on different masonry bonds. These were important to obtain sufficient stability in solid masonry walls and were considered as especially important for a sound structure.

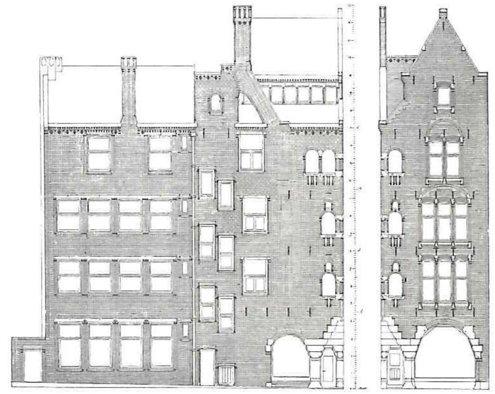

Fig. 1

During this period, one began building cavity walls. The introduction of the cavity wall did, however, not lead to diminished attention for masonry bonds. The following reasons for installing an air space (cavity) in the, up until that moment, solid load-bearing walls were put forward in the professional literature:

- sound insulation;
- keeping out warmth and cold;
- preventing moisture from the external wall spreading through the interior wall.

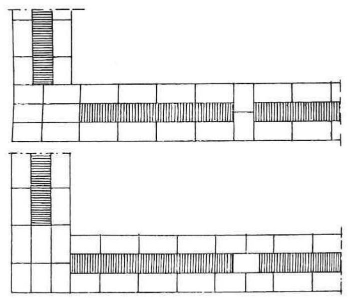

Fig. 2

With the increased use of the brickwork cavity wall, a distinction arose between the load-bearing part and a non-load-bearing part of the external wall. That is not to say that the importance of a certain part of the wall is greater than of another part, but one can speak of a separation of functions. Technically, part of the wall will fulfil a load-bearing function and the cavity in the wall is used in order to solve building physics problems.

At the introduction of the cavity wall there was uncertainty about the position of the cavity itself and the half-brick wall. At that time, it was common practice to place the cavity wall on the inside and the load-bearing wall on the outside. Only a 'single master builder' could be found, who made the cavity wall on the outside of the load-bearing wall (from the outside; first the half-brick wall followed by the cavity and the load-bearing brick wall entirely inside).

1912

The draft revision of the Housing Act, Amsterdam Housing Council, Amsterdam: J. H. de Bussy. In professional literature the application of masonry cavity walls is frequently mentioned.

During this period special attention was paid in professional literature to the building physics effect of the masonry façades and the existence of thermal bridges. Terms such as 'cavity cleat' were introduced and their application led to considerations on 'optimal insulation'. In cavity walls the brick inner and outer leaf were still connected at the window frames. Moreover, it was customary to render both the inner and outer cavity leaf with a layer of cement slurry. Due to the small size of the cavity (generally about 6 cm), both walls could not be built too high, as the layer of cement slurry could not be applied. Owing to the mortar droppings as a result of rendering the advice was to commence the cavity considerably lower than was actually necessary.

First mentioning of thermal bridges in brickwork façades. The cavity was still bricked up at points where the load-bearing capacity needed to be increased and at points where the two walls needed to be kept together. The latter occured by means of connecting bricks, which would be an extremely hard type and immersed in boiling tar beforehand. Many 'structural engineers' achieved lesser results with such walls. As a result contractors started to connect the two walls together by means of iron anchors, so-called cavity ties.

Cavity ties made of galvanised iron wire or a flat piece of galvanised steel were used. The middle part of the tie is taken standing, so that the chance that left mortar droppings resulting in contact between both walls would be as small as possible. The cavity ties were fitted every 4 to 6 layers in a staggered pattern at intervals of 0.70 m to 1.00 m. (Fig. 4)

The introduction of bricked-in frames and buck frames. One did not brick up the walls by the window frames and the structure is built as indicated in fig. 3.

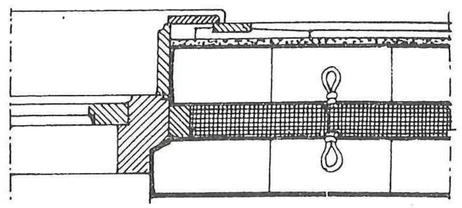

Fig. 3

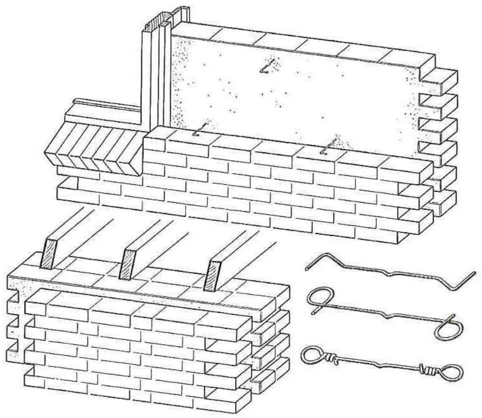

Fig. 4

Various publications show that spans above openings in external walls were mainly made in natural stone or brickwork. Also load-bearing window frames were commonly used, which Prof. J. G. Wattjes described very clearly in his publications.

While at first instance the spans over openings were still made in brick and natural stone, solutions using steel and concrete were also applied ultimately. In this period developments in reinforced concrete structures, in particular, were adopted easily in the architecture of brickwork façades (fig. 5: note the load-bearing outer leaf of the façade). The latter is also logical given the fact that the reinforced concrete elements were not only made in situ, but were also offered as prefabricated elements. The name 'man-made natural stone' or 'betonno' appeared regularly in the literature. These types of products were at that time not so limited in terms of their structural possibilities and gave a lot more security for large spans.

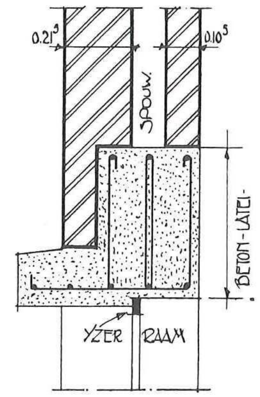

Fig. 5

Introduction of brickwork reinforcement in the thin leafs of cavity walls. (Fig. 6)

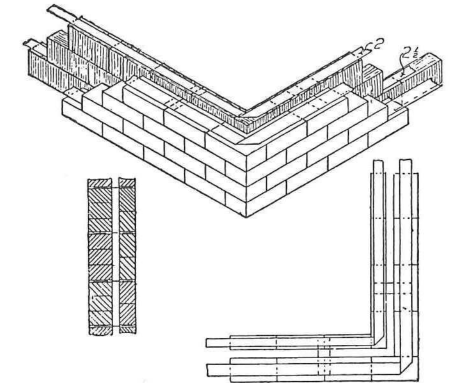

Fig. 6

1921

Revision of the Housing Act.

Introduction of prefabricated flues and chimneys replacing the traditional brick flues and chimneys.

Professional literature described the possibilities to make spans with rowlock courses without a load-bearing window frame. It was important that the spans are not too large and that no beams were placed in the brickwork above these rowlock courses. If there was no frame present, or the frame was not considered load-bearing, it was recommended to use rowlock courses with a height of at least ⅔ of the span. The brickwork next to the opening should have a width of at least ⅔ of the width of the opening. It is clear that these sorts of dimensioning rules had a considerable influence on the design of brickwork façades.

Fig. 7

Introduction of 'breast summers': iron beam covered with pieces of natural stone. There was a great aversion to this way of spanning the opening both structurally and architecturally. It was deemed better to use reinforced concrete or 'betonno' in these types of situations.

Less decorated façades and ornaments. Extensive construction of housing with a uniform architecture in the period after the First World War. (Fig. 7)

1931 Revision of the Housing Act. This made it necessary to adapt the Model Building Regulations to the new statutory regulations.

1933 Adaptation of the Model Building Regulations.

In England the mechanical engineer Henry Dyke concluded at the beginning of the 1930s that it should be possible to prefabricate high-quality brickwork elements. Dyke was granted a patent for the system he devised in 1933 and started marketing it with his company Simplified Brick Construction Ltd. The brick in combination with an air cavity formed the basis of the system. In addition, the prefab elements consisted of concrete inner leaves, which could vary in thickness depending on their application.

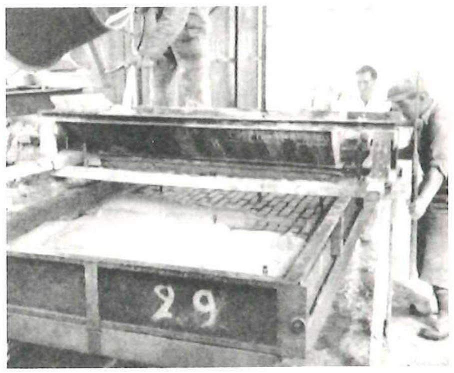

Fig. 8

1947

National government stimulated industrial building systems to meet the great demand for housing after the Second World War.

1949

Stimulation of industrial building systems and national granting subsidies resuled in the development of the BMB system *(Baksteen Montage Bouw)* that was largely based on Henry Dyke's brickwork façade system.

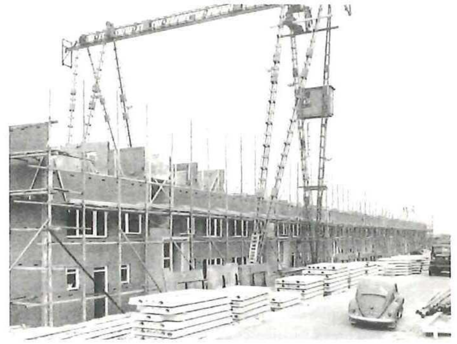

Fig. 9

1950 Reconstruction Act *(Wederopbouwwet)*: Article 20 offered opportunities to deviate from the Model Building Regulations and development plans, ample use of which was made. The law was only supposed to be in effect for 3 years, but ultimately remained in force until 1970.

1952 Model Building Regulations (*Model Bouw Verordening*, MBV 1952). The construction of brickwork buildings primarily occured on the basis of the table in the Model Building Regulations, because this gave simple rules for low-rise and medium-rise buildings (no more than 5 storeys, possibly on a substructure, provided that it was not higher than 2.2 m). The MBV set the following requirements for making cavity walls [art. 172]:

- the joint thickness of both leaves of a cavity must at least possess the required total thickness as indicated in fig. 10;
- the cavity cannot be wider than 100 mm and no thinner than 50 mm and must be lightly ventilated with fresh air;
- extra loads are not permitted without sufficient reinforcement;
- the total height of the wall built as a cavity wall may not amount to more than 7 m for load-bearing walls and 10.5 m for other walls, unless both parts of the walls have a joint thickness of 300 mm or measures against buckling have been taken in another way.

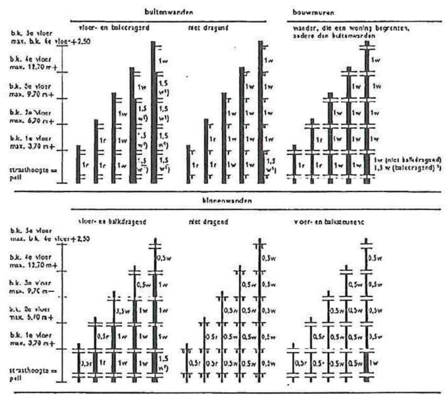

Fig. 10

Start of automation in brick factories by the application of measurement and control engineering for the production. Kilns could operate autonomously without human interference.

1955 N 1055 – Technical Principles for Building Regulations (*Technische Grondslagen Bouwwerken*, TGB 1955). Central Office for Standardisation, Royal Dutch Society of Engineers, Netherlands Society for

Industry and Trade and Head Commission for Standardisation in the Netherlands.

The N 1055 connected construction theory and practice albeit in an artificial way. Around 1920, standardisation began in the Netherlands, whereby Germany was taken as an example. In 1922, the first standard sheets for steel structures were introduced, followed in 1940 by the Reinforced Concrete Regulations, N 1009 (*Gewapend Beton Voorschriften*, GBV 1940). The N 1055 was published for the first time in 1949 and the second, revised eidition appeared in 1955. Masonry was only dealt with briefly, and in the case of reinforced concrete, reference was made to the Reinforced Concrete Regulations, N 1009. The norm primarily delt with steel, cast iron and wood.

1956

Governmental Uniform Building Regulations Decree (*Besluit Uniforme Bouwvoorschriften*, BUB)

Insofar as the requirements of the municpal building regulations exceeded the provisions of this decree these requirements were suspended. In the decree, a large number of standard sheets were declared binding (TGB 1956, GVB 1950 and suchlike) with which a good connection was established with the prevailing buiding techniques.

1960

The cavity wall was made obligatory for façades in the Model Building Regulation.

The introduction of tunnel kilns for the production of bricks.

1964

NEN 1068:1964 – Physics Principles for Building Regulations (*Natuurkundige Grondslagen voor Bouwvoorschriften*, NGB) Thermal properties for residential buildings. Prescribed R_c value of the exterior wall of 0.43 m² K/W.

Development of thin bed mortar for sand-lime blocks, based on the thin bed mortar for aereted concrete blocks (in those days the brandname of the aereted concrete blocks was Durox).

Without insulation in the cavity of an external wall, it was possible to achieve the required R_c value of 0.43 m² K/W with a brick cavity wall.

1965

Adapted version of the Municipal Model Building Regulations (*Model Bouw Verordening*, MBV 1965). This publication is the Model Building Regulation to date.

Article 160 from the MBV 1965: Protection of walls against rising and splashing damp. A layer must be present in walls or columns that stand in contact with the soil or water which prevents dampness occurring to the part of the wall or column situated above the soil or the water. In walls or columns, which are exposed to rain, the layer mentioned must consist of a brick damp course, which:
- is at least 60 cm high;
- reaches at least 25 cm above the height of the adjoining terrain;
- reaches above ground present on the inside of the wall;
- reaches at least 25 cm below the underside of the lowest floor, which is situated above the adjoining terrain.

The MBV prescribed a minimum ventilation for the cavity wall, which was set at 1000 mm² on the lower and upper side per meter of a surface of a cavity wall.

Introduction of 'Principles and suggestions for the design of residential buildings', which was applied as a precondition for governmental subsidies.

Façades could still be executed in solid brickwork with a minimal thickness of 300 mm. For the anchoring of the two parts of a cavity wall, round, galvanised ties with a thickness of 4 to 6 mm were required. Other solutions were permitted however the strength and resistance to corrosion was not to be less than standard ties and solutions would not give rise to the formation of moisture bridges between both sides of the cavity wall.

Requirements regarding thermal and sound insulation, rain and moisture proofing of the façades of buildings intended for occupancy were determined. This resulted in the obligation to apply cavity walls for residential buildings and also for insulation material in the cavity wall in special cases.

1966

SBR publication no. 8: Cracks in residential buildings *(Scheuren in Woningen)*. Based on a research into cracks in residential buildings after 1945.

First recommendation with regard to the application of expansion joints in brickwork walls and façades [fig. 11].

First publications appeared about the application of expansion joints in brickwork façades that needed to be applied in the case of wall parts having to move freely from another.

In this period, more attention was given to the climate influence on the behaviour of façades and roofs. Up until this period attention was paid to cracks resulting from poor foundations or insufficient provisions close to wall openings. However, an increasing amount of cracks arose in the period from 1945, which were the result of heat and dampness influences. In this period, these cracks were also partly explained by the simultaneous application of various stone-like materials in one building (concrete, brick, lightweight concrete, sand-lime brick), while brick was used exclusively previously. The use of stone-like materials for floors and roofs was seen as the cause, as a result of the situation that adjoining structural members impeded each other movements.

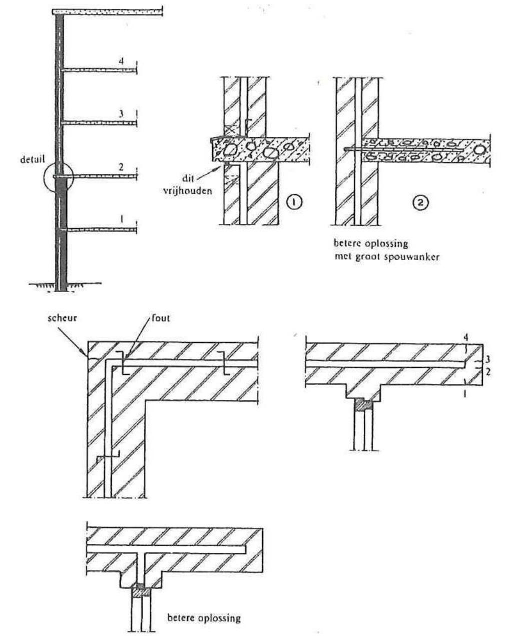

Fig. 11

1972

NEN 3853 – Technical Principles for the calculation of Building Constructions – TGB 1972 – Brick, Brick constructions.

In this national standard, just like the Model Building Regulation, design tables were included for a limited application area, in which the required quality or dimensioning of brickwork could be read directly.

The outer cavity leaf was increasingly separated from the main load-bearing construction, as a result of the acquired knowledge regarding cracking in brickwork façades. The total height of outer cavity leaves was limited to 10.5 m. It was possible to deviate from this height, if it could be proven through a calculation that a certain wall height was structurally sufficiently strong.

Introduction of brick setting machines for the production of prefabricated brickwork façade elements (for example Danilith in Belgium).

The Morres masonry robot was presented at the International Exhibition of Inventions and New Techniques in Geneva. The machine had a capacity of 6000–8000 Waal-size bricks per day.

1973

The first oil crisis raised the discussion about the restriction of energy consumption and the insulation of residential buildings. In the following years many residential buildings were post-insulated by applying insulation in existing cavity walls. First regulations were drawn up regarding the façade insulation of residential buildings. There was still little attention for the insulation of brickwork façades, but the first ideas developed as a result of the discussion about the availability of fossil fuels.

Under the influence of the oil crisis, the prefab brickwork factory Sterk from Rossum developed an insulating brick wall element. It concerned an improvement and further development of the well-known BMB system.

1975

Prescribed R_c value of the exterior wall of 0.69 m² K/W in the NEN 1068 and in Model Building Regulation.

The development of large sand-lime elements for interior, load-bearing walls. The modulair elements (600 × 900 mm) needed to have limited tolerances, this and the use of thin bed mortar were important for the mechanical application of these big elements.

The introduction of this sand-lime system ultimately resulted in the almost exclusive application of bricks in façades and no longer as a structural, load-bearing inner cavity leaf or load-bearing wall structure.

1976

The brick industry advised in its documentation to take measures in order to prevent cracking in brickwork walls and façades. In the first instance, this was not so much advice to apply expansion joints, but was more like advice to prevent the cracks and expansion joints (the advice was focused on the prevention of cracks by using the correct materials and good details). Detailed solutions were given for façade corners and recommendations with regard to the maximum dimensions of brickwork façades that did not have to be provided with expansion joints. In closed façades the rule was applied that brickwork façades of 3 metres high could be built up to a length of approximately 20 metres without expansion joints (about 7 times the height). It was also indicated that as the wall becomes higher, the risk of cracking decreases.

The presence of openings in the external wall would, however, once again result in a decrease of the distance between the expension joints, because this was considered as weakening in the façade. It was also noted that the composition of the mortar influences the distance between the expension joints. In the case of a lime mortar this distance could be larger than in the case of a cement mortar.

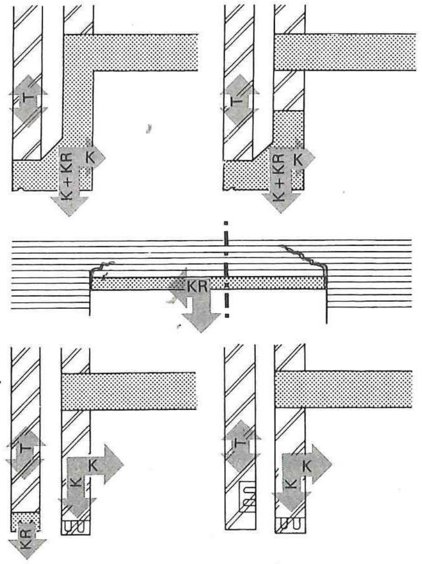

Fig. 12

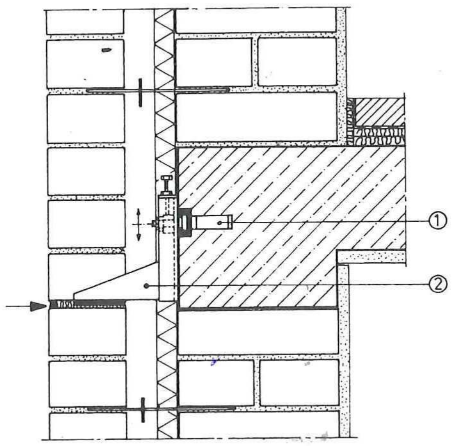

Fig. 13

The application of load-bearing brickwork expanded considerably. Earlier, brickwork was only applied for houses or buildings of a limited height to support (wooden) floors with a small dead weight and relatively small span. In this period load-bearing brickwork in buildings up to a height of 8 to 10 storeys was applied in combination with relatively heavy concrete floors up to spans of 7 to 8 metres.

The more extensive use of steel wall supports replacing protruding concrete floor slabs primarily at brickwork gables of high-rise buildings. The horizontal provision of expansion joints in brickwork façades was generally advised and also executed this way.

1982

Introduction of computer systems in the production of bricks, which resulted in an optimal production process and benefited the quality of the bricks.

1983

Prescribed R_c value of the external wall of 1.3 m² K/W and double glazing in the living rooms.

The reinforcement of the isolation requirement made it increasingly more difficult to make cavity walls with the usual, average cavity size of 60 mm.

1984

Partial abolition of the 'Principles and suggestions for the design of residential building (1965)' as condition for governmental subsidies. Wider use of the Model Building Regulation (*Model-Bouwverordening*, MBV).

NEN 1068: 1981 – Thermal insulation of buildings – Terms and calculation methods for stationary situations.

1985

Supplement to NEN 3853 – Technical principles for the calculation of building constructions – TGB 1972 – Brick, Brick constructions.

1986

For the dimensioning of brickwork structures, the Model Building Regulations soly refered to the NEN 3853 since the publication of the 22nd supplement (December 1986).

1987

BRIK project (Brick Research Innovation and Knowledge Transfer, BRIK) of the Royal Dutch Association of Brick Manufacturers (*Koninklijk Verbond van Nederlandse Baksteenfabrikanten*, KNB).

The promotional campaign 'Beauty is masoned in Brick' (*'Mooi is gemetseld in baksteen'*) resulted from the BRIK project. Following the BRIK project, the jointing of brickwork façades (as opposed to the traditional pointing) was stimulated and also the development and stimulation of the glueing of bricks. Regulations in the field of both load-bearing brickwork as well as external brickwork were also stimulated by the industry.

Research in brick is set in motion through this programme, to gain market share in the total construction production. Brick was often outset by materials that could be applied faster or appeared to be cheaper despite the knowledge that the maintenance costs and life span of these materials turned out to be much less favourable than expected.

Research started into:

- masonry techniques: tools, means of transport, mortar application equipment, brick lifting machine and finish and cleaning;
- prefabrication systems: lintels, wall sections and working methods with these techniques;
- binders / glues: for façades and interior walls;
- structural applications;
- patents.

MOOI
IS GEMETSELD IN BAKSTEEN

Fig. 14

1989

Prescribed R_c value of the exterior wall of 2.5 m² K/W in the Model Building Regulation (24th supplement).

Insulation on the basis of an R_c value of 2.5 m² K/W in roofs and façades and 1.3 m² K/W in ground floors

1991

NEN 6790: 1991 – TGB 1990 Brick structures - Basic requirements and assessment methods.

Various publications by the Royal Dutch Association of Brick Manufacturers concerning brickwork façades and expansion joints. Vertical expansion joints were advised at intervals of 10 m to 12 m and at the corners. The width of the vertical expansion joint was set at 3 mm. Horizontal expansion joints were advised for façades higher than 10.5 m based upon the old TGB 1972 (NEN 3853) that specified this height as maximum height for half-brick masonry in the façade. Difference between building physical and structural expansion joints were set out in various publications.

Increasing attention by architects for the possibilities of formed (wire cut) bricks for the creation of special textures in brickwork façades.

The Royal Dutch Association of Brick Manufacturers started to advice not to use frame anchors in the outer leaf of cavity walls.

1992

The governmental Building Decree and the revision of the Housing Act comes into effect on October 1st. 1992. As a result of the Building Decree uniform technical building regulations came into force. The regulations were formulated as much as possible in performance requirements, which were again based on functional descriptions. The regulations were measurable and verifiable, and at the same time they had to restrict freedom and innovation as little as possible.

Prescribed R_c value of the exterior wall of 2.5 m² K/W and double glazing in all heated rooms.

NEN 2686: 1988 - Air permeability of buildings - Measurement method. This standard was made applicable for the airtightness of buildings in the Buildings Decree of 1992.

Introduction of thin layer mortar for brickwork façades, commonly known as glue mortar. Main difference with traditional mortars was the higher bonding strength, that offered new structural possibilities.

Due to thicker insulation, a larger distance arose between the inner- and outer cavity leaf, as a result of which the support of the outer cavity leaf became increasingly important (cavity ties, wall supports, connections etc.). The most common dimensions of a brickwork cavity wall became 300 mm (100-100-100).

Development of the heat wall and increasing attention for the heat-accumulating capacity of stone-like materials. Low temperature heating systems became more interesting in the context of the reduction of the energy consumption of buildings.

The surface of windows and doors in the façades was restricted to 25% of the usable area. A certain measure of airtightness was required by the Housing Act.

1993

CUR report 93-2: Detailing with brick - Prevention of visual damage due to pollution and CUR report 165: Sustainability model for brick masonry.

CUR recommendations were publications in which agreements between parties in the construction industry were laid down; they were thus communicative documents. A CUR recommendation was the best technical advice that could be given about a certain subject at that time in question. It included broad technical rules which made it possible to use new materials and / or new (structural) applications, for which there were not yet accepted rules. The content of a CUR recommendation had the character of a standard. Due to the support, CUR recommendations were viewed as prenormative documents, as long as no norm relating to the subject in question was in force. CUR recommendations were drawn up by CUR regulation committees. The support was guaranteed due to the fact that the users and the relevant market players were part of these committees.

There was much attention for the improvement of the quality of the brick façades. Various publications and guidelines for architects were made by the industry, together with specialists, engineers and scientists.

1995

Introduction of the energy performance standardisation in the Building Decree and also the energy performance coefficient. Compulsory EPU of 1.9 and EPW of 1.4 (EPU = Energy Performance Nonresidential Building; EPW = Energy Performance Residential Building).

Publication by the Royal Dutch Association of Bricks Manufacturers of 'Calculation rules and expansion joints', which replaced the 'Manual for expansion joints in brick façades'.

Development of a modular brick, based on the gluing of brick (HSL system). The bricks were only 80 mm thick in stead of the common thickness of 100 mm, which allowed to achieve the required R_c value of 2.5 m² K/W within the original 300 mm thickness of the brick façades.

GOVERNMENTAL REGULATIONS / NORMS
INDUSTRY-DRIVEN REGULATIONS

TECHNOLOGY AND CONSTRUCTION METHODS
MATERIALS AND APPLICATIONS

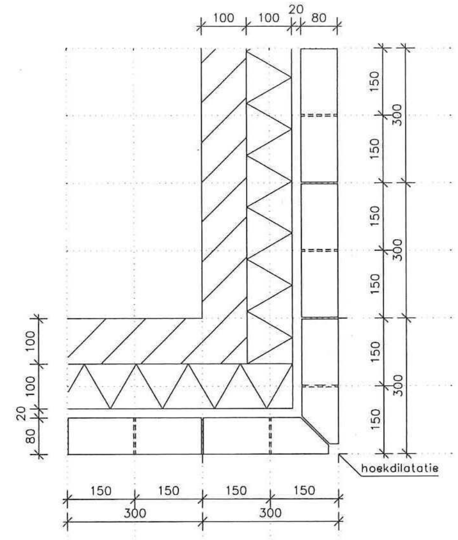

Fig. 15

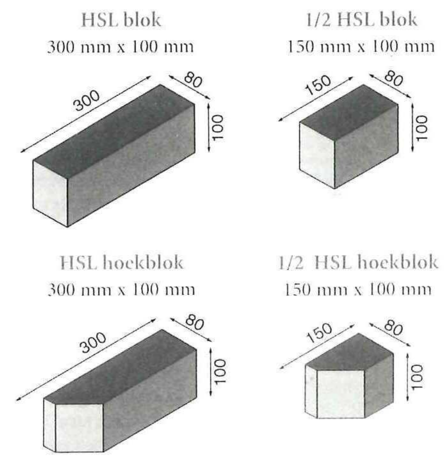

Fig. 16

1996

CUR Recommendation 46: Diaphragm walls in brickwork.

A partial aim of the BRIK research programme was to increase the structural application of brick masonry. Research was conducted into load-bearing brickwork and one of the results of this is the application of brick external wall structures as load-bearing and stabilizing walls for buildings.

1998

Introduction of a mortar for thin joints as an alternative to gluing bricks. This mortar could be applied with a trowel in stead of a pomp.

2000

Raised EPC requirements for residential and nonresidential building: EPU of 1.4 and EPW of 1.0.

CUR Recommendation 71: Structural aspects in design, calculation and details of brickwork façades and CUR Recommendation 73: Stability of brick structures.

In spite of the raised EPC requirements, construction was still possible on the basis of a R_c value of 2.5 m² K/W for façades.

Clear and simple guidelines for the provision and placing of expansion joints in brickwork façades taking different types of joints (such as structural and building physical expansion joints) into account.

The application and execution of corner expansion joints was determined, as a result of which clarity was also created with regard to no longer apply anchorless corners. More attention was given to structural expansion joints in the brickwork façades. These expansion joints were, in general, the consequence of connecting the outer brickwork leaf to the underlying construction, or the placement of brickwork on a structure that can deform. The size of the vertical expansion joint in brickwork was set at a minimum of 5 mm.

There was a need for regulations regarding the static calculation of brickwork façades. Not only was there a discussion concerning the interpretation of regulations, but existing regulations appeared not to cover all structural aspects. Brickwork façades were further subject to changes, whereby the increasingly larger cavity in combination with the application of thicker insulation material played an important role. In addition, increasingly more expansion joints were applied in façade structures to prevent cracking which also requires clearer regulations. The construction techniques were also changing and consequently also the façade details.

2001

CUR Recommendation 82: Control of cracks in brick structures.

The building production was at its peak in this period. Brickwork façades were often applied and the demand for prefabricated brickwork increased. A number of manufacturers switched to (further) development of prefabricated brickwork façade systems. The increased knowledge of alternatives of joining bricks (eg. glue), supported the improvement and development of façade systems.

2003

Revision of the Building Decree (1st of January 2003).

Publication by KNB of the brochure Designing with expansion joints *(Ontwerpen met dilataties)*, which replaced the brochures about the subject published earlier.

Introduction of the Daas *ClickBrick*; a system for dry stacking of bricks in façades.

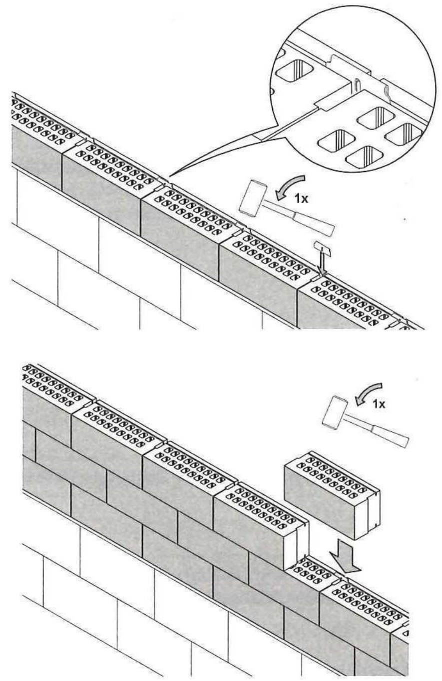

Fig. 17

2005

NEN 6790: 2005 – Technical Principles for Building Constructions – TGB 1990 – Brick structures - Basic requirements and assessment methods. Improvements of the NEN 6790 issued in 1991 and lining the national norms up with Eurocodes.

2006

The application of jointing mortar on a larger scale replaced the traditional 'after' pointing of the joints.

Development of a masonry robot at the ETH in Zurich, which ultimately resulted in the masonry robot R-O-B. Introduction of the digital materialisation of façades and objects like columns.

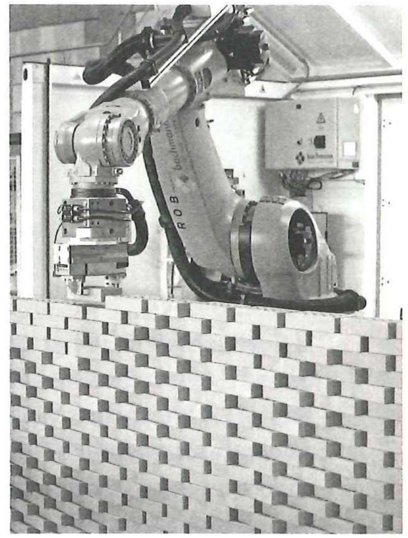

Fig. 18

2009

NPR 6791: 2009 – Brick constructions – Simple design rules, based on NEN 6790: 2005.

2010

Polyurethane glueing of stone-like materials with help of a spray can. For example PU-700 Stone glue.

2011

Introduction of the European masonry standards:

- NEN-EN 1996-1-1 + C1: 2011 NL – Eurocode 6 – Design and calculation of masonry structures – Part 1-1: General rules for structures of reinforced and unreinforced masonry
- NEN-EN 1996-1-1 + C1: 2011 NL – Eurocode 6 – Design and calculation of masonry structures – Part 2: Design, choice of material and execution of masonry structures.
- NEN-EN 1996-3 + C1: 2011 NL – Eurocode 6: Design and calculation of masonry structures – Part 3: Simplified calculation methods for structures of unreinforced masonry.

Besides the use of NEN 6790 and NPR 6791, it was allowed to use also the European masonry standards.

The provision of expansion joints and the interval between expansion joints was included in the standard for the first time. In general, recommendations for applying expansion joints was provided by the manufacturer. In the case of brickwork façades, the following intervals between the expansion joints applied:

- north façades: 14 m;
- other façades: 12 m;
- parapets with height h: < 5 h.

If expansion joints in building corners were to be avoided, expansion joints should be applied in both external walls, which are situated at a maximum of 3.0 m from the corner, where across a length of 0.5 m no cavity ties might be included on both sides of the corner.

In the case of parapets that continue around the corner, the expansion joints should be situated at an interval of maximum 2.5 h from the corner in both walls.

Vertical expansion joints should be executed as an open joint (5 mm wide) or as a filled joint (10 mm wide and provided with an elastic backfilling sealant).

2012

Revision of the Building Decree as of 1-7-2012.
Prescribed R_c value of the external wall of 3.5 m^2 K/W.

NPR 9096-1-1: 2012 NL – Brick constructions – Simple design rules, based on NEN-EN 1996-1-1 + C1: 2011

It became more difficult to design and build a brickwork cavity wall of 300 mm, with a cavity of 100 mm. The standard dimensions of a common cavity wall increased, and became 340 mm to 360 mm. The size of the cavity depended mainly on the type of insulation material.

As a result of the increasing requirements with regard to the insulation value of the façade and the prevention of too much loss of floor space in the buildings, solutions with thinner brick external wall systems were developed. This concerns both systems that were based on glueing brick facing strips on insulating material, as well as systems with brick facing strips that were glued on sheeting material.

In addition to these systems, thinner bricks were also produced, which ultimately resulted in an outer cavity leaf thickness of 60 to 70 mm. Brick-on-edge course Waal-size bricks were also used in glued façades.

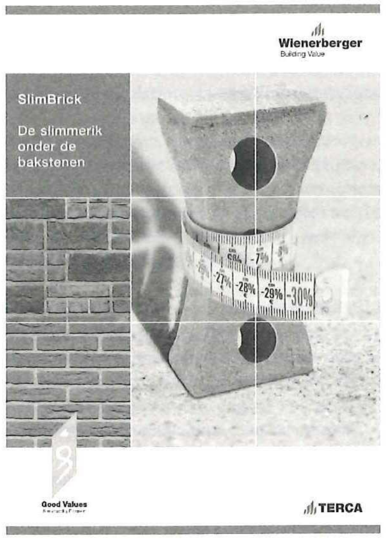

Fig. 19

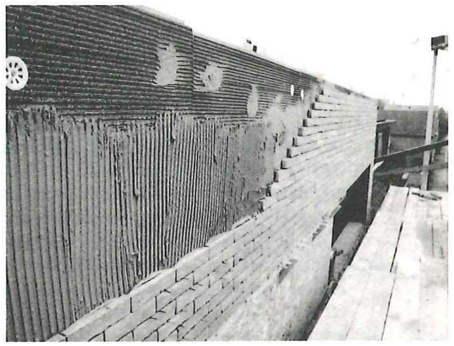

Fig. 20

2014	1-7-2014 – Exchange of the dutch codes by the European codes: - NEN-EN 1996-1-1 + C1: 2011 NL – Eurocode 6 – Design and calculation of masonry structures – Part 1-1: General rules for structures of reinforced and unreinforced masonry - NEN-EN 1996-1-1 + C1: 2011 NL – Eurocode 6 – Design and calculation of masonry structures – Part 2: Design, choice of material and execution of masonry structures. - NEN-EN 1996-3 + C1: 2011 NL – Eurocode 6: Design and calculation of masonry structures – Part 3: Simplified calculation methods for structures of unreinforced masonry.	In addition to the thin brick experiements were made with the application of self-supporting façades with brick masonry. The advantage of these type of façades was the limitation of the joints to the outer cavity leaf, so that the insulation of the façade structure was optimal and is not interrupted by cold bridges.
2015	Revision of the Building Decree as of 1-1-2015. Prescribed R_c value of the external wall of 4.5 m² K/W.	It became more difficult to design and build a brickwork cavity wall of 340 mm, with a cavity of 140 mm. The standard dimensions of a common cavity wall increased, and became 360 mm to 390 mm.

Jeroen Geurst

BRICK: ON SIZE, SCALE AND ORDER

'If you want to play the game of architecture,
you should know the rules of the game.'
— Edwin Lutyens

Brick has a major impact on how we perceive cities. In the Netherlands, it is still the dominant construction material used for façades and streets. The use of brick gives the façades that line the streets and squares mass and scale, and it highlights the craftsmanship of the maker. These façades appear heavier than wooden or steel ones, and as such they provide the urban space surrounding us with a more solid perimeter. The size of the buildings and streets, and therefore the size of the public space, is measurable since it is derived from the size of the brick so familiar to us. The measurement of the smallest unit in a façade, the brick, is determined by its production method, one that is often hand processed. During the architectural design process, this requirement, which emanates from the material, seems to barely play a part. The proportions of the façade are usually translated in terms of the brick's headers and stretchers. There are only a few examples of the opposite, where the measurement of the brick is the starting point for the dimensioning of the plan, the cross section and the façade. The following is a reflection on the work of Sir Edwin Lutyens and the work of Geurst & Schulze architects examining the use of a principal whereby the size of bricks is used as the basis for the dimension and proportion of façades within the limitations of current regulations and construction practices.

THE HUMAN SIZE OF BRICK AND THE SCALE OF BUILDINGS

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The measurements of the most commonly used bricks are historically determined by the amount of clay that can be formed with one hand: the hand-moulded brick. Although the mechanization of brick production has made it possible to produce larger bricks now, it is still the hand, in this case that of the mason, that determines the measurements of the brick. In brick buildings, we can relate height and width to the measurements of the brick and therefore to