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Berlage's Beurs – concept and method

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In the eighteenth century Dutch architecture still flourished, but it went into deep decline in the early nineteenth century. It was only in the second half of that century that building in the Netherlands made a fresh start. It was with the generation of Berlage, and his somewhat younger colleagues, that the new architecture began to reach international attention.

The Exchange building in Amsterdam became the touchstone for the new architecture. Built between 1898 and 1903 the development of its design shows in plan, section and perspective how, little by little, the definition of a new architecture began. In this paper various elements of the building which require deeper enquiry than has been accorded until recently, are investigated. First, the riddle of the basic measures (the vertical and horizontal modules) related to brick sizes and bonds and the proportional system of the Beurs in plan, section and elevation are analysed. This is followed by an investigation into why Berlage changed the form of the trusses of the main hall in the period between the production of the specification drawings and the start of the construction works.

The preliminary studies

Although the preliminary studies for Berlage's Beurs, or Stock Exchange, have been extensively written about[1] one of the most remarkable factors is that any Exchange in Amsterdam was expected to be built on the bed of the (former) Amstel river (Fig. 1).[2,3] Berlage knew very well the history of the Beurs's two predecessors and the settlement that had occurred in both cases.[4] He mentioned this in his well-known Beurs lecture given on April 1, 1898, for his colleagues at the Architectura et Amicitia club in Amsterdam when presenting the plans for the Stock Exchange.[5] Yet he built the Beurs in the same boggy area. Did he therefore regard this as a challenge?[6] It is of interest to know whether, and if so how, Berlage reacted above the level of the pile caps to the subsoil conditions and whether the structure of the building, as we perceive it, adapted to the specific character of the subsoil.

At other levels also, one understands the prehistory of the Beurs with difficulty. Why did Berlage receive the commission having come second in the competition? (Figs. 2 and 3.) On the basis of what data did he start his design? Why, for example, was he obliged to use a ground plan conceived by A. W. Weissman, the city architect, in 1887? (Figs. 4, 5 and 6.) What other ideas from Weissman's design did Berlage adopt? We do not know either what was the theoretical background for the geometry on which Berlage later laid such emphasis or the methods for static calculations known at the time. Had he mastered such techniques as the graphostatical method of Cremona (1871)? What did he know about new materials and their physical qualities? In the publications on Berlage, Gottfried

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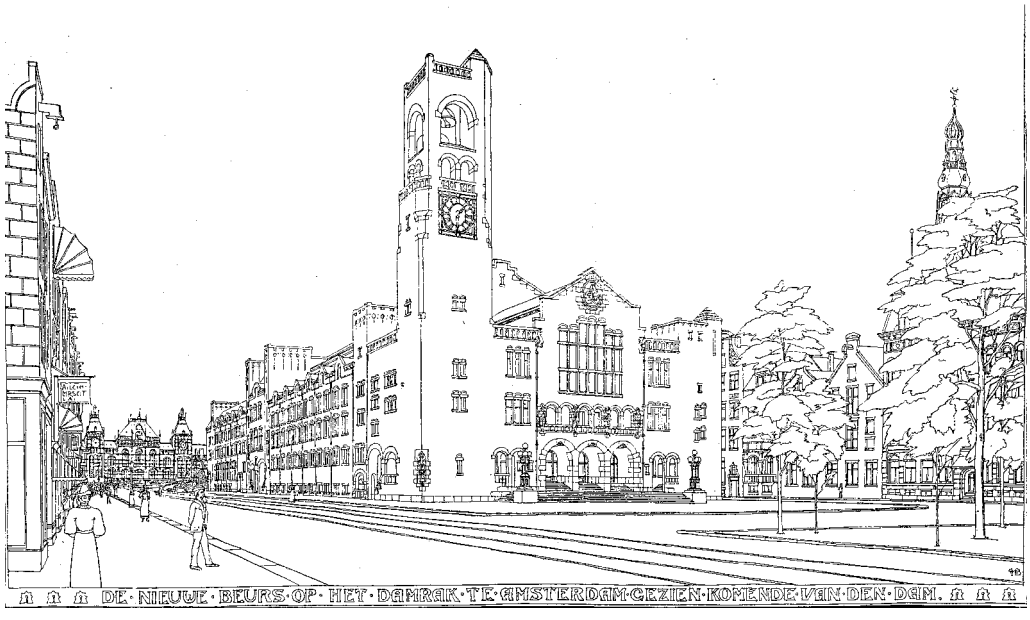


Figure 1. Perspective towards the east with the Central Station by Pierre Cuijpers in the distance (*Architectura*, no. 12, 1898).



Figure 2. Second design for the new exchange in the international competition; watercolour by H.P. Berlage 1885 (in *Topografische Atlas van gemeente Amsterdam*).

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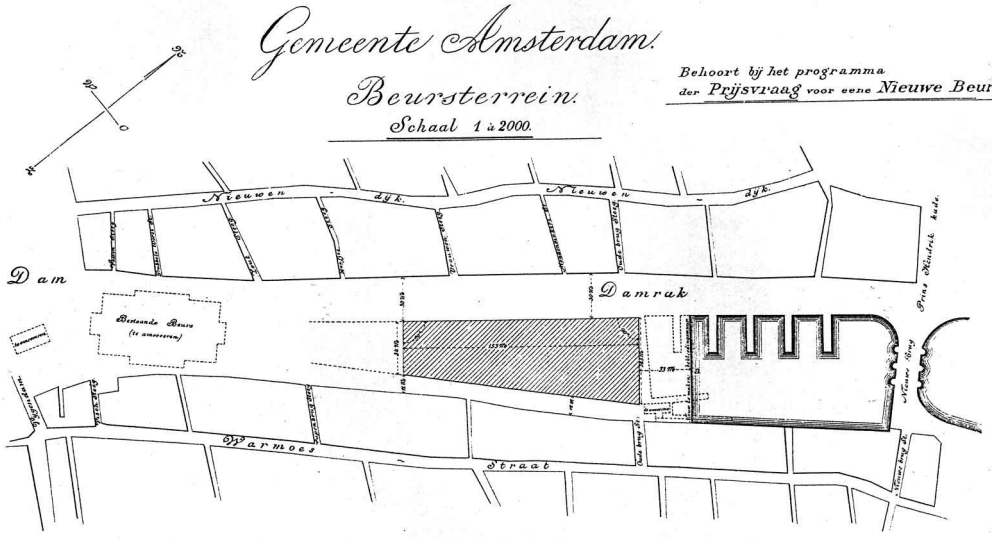


Figure 3. Situation as for the international competition in 1885. To the left the Damsquare with the Zocher beurs to be removed; the water to the right is the last part of the Amstel river over which the Dam was built centuries ago. (*Bouwkundig Weekblad*, 5, 1885.)

Semper and Eugène Viollet-le-Duc have been mentioned frequently as Berlage's main theoretical sources and inspiration. But their views were based on knowledge developed before 1870. In 1895 their writings were in many respects superseded by new developments. Stability, for instance, was a notion the meaning of which had changed fundamentally in the third quarter of the nineteenth century. Empirical and theoretical research on materials had been developing rapidly and improvements in the iron industry led to the application of steel in the building trade. This knowledge is absent from the writings of Berlage's instructors and from his own writings, so it is not possible to trace whether Berlage had studied other theoreticians.

Berlage's theories

In his famous lecture in Zürich (1907), of which the text was published in 1908 under the title *Grundlagen und Entwicklung der Architektur*, Berlage defines very precisely how one should look at a building before criticising it. He starts with a quotation: 'Time alters fashions . . . but that which is founded on geometry and real science will remain unalterable'. He continues:

> Yet also I see Sheraton's motto as correct and dare to make it mine, right because it concerns a reflection about art, more precisely the art of building (. . .). I have come to the conviction that geometry, the mathematical science, for the making of artistic forms is not only the most profitable but even absolutely necessary.

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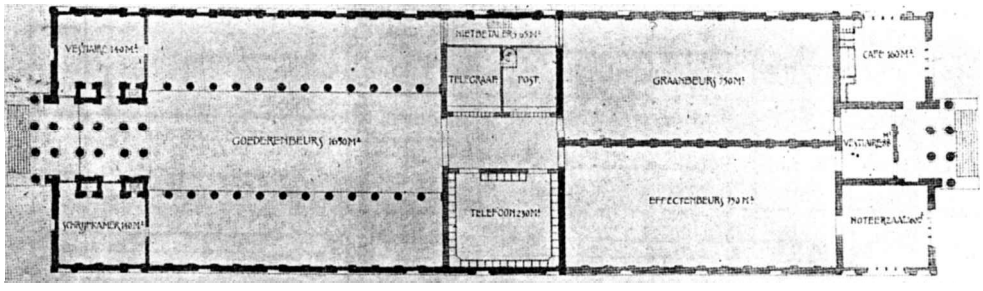


Figure 4.
A.W. Weissman's project of 1894 for the refurbishment of the existing Zocher beurs; groundplan as suggested to Berlage. Weismann was the Amsterdam City Architect.

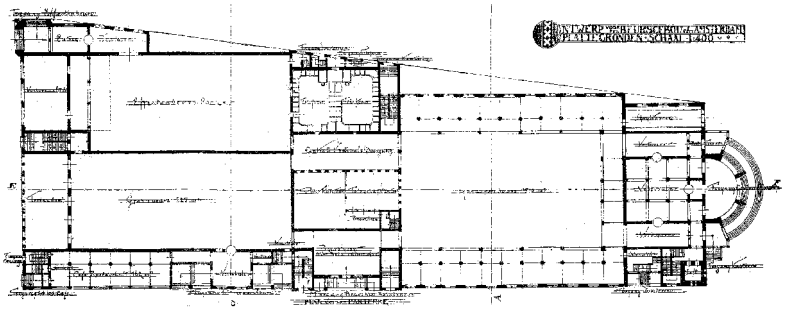


Figure 5. Berlage's groundplan drawn for the city council meeting on October 7 1896. (Published in *Bouwkundig Weekblad*, 39, 1896.) As Weissman wrote to the City Council, the design is nearly the same as for the refurbishment of the existing Exchange as he himself had drawn it up on request of the City Council in 1894.

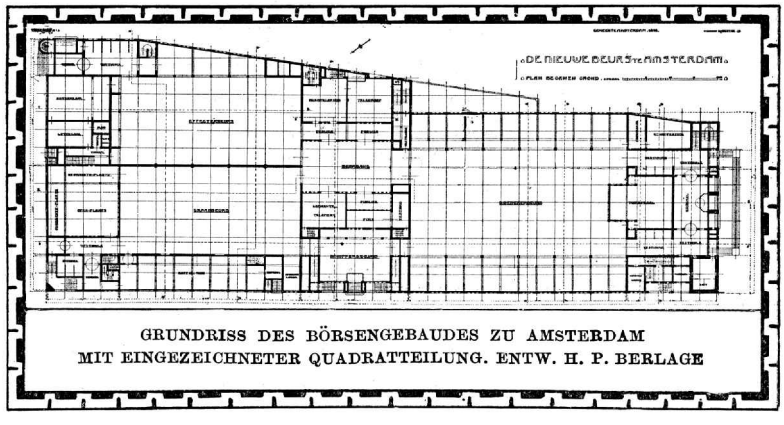


Figure 6. Groundplan as for the specification for bids and as published in Berlage's *Grundlagen und Entwicklung der Architektur* (Amsterdam, 1908) with dimensions and grid of 3.80 m × 3.80 m.

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Evidently Berlage's lecture was influenced by theories concerning the coherence of the universe which had been developed contemporaneously:

> And while now these shaping/creative/formative laws (Gestaltung) in the whole universe are of the same mathematical nature, that is where it concerns the bodily stereometric and where planes are concerned with the geometric.

Essential to an understanding of Berlage's work is what he said in the same lecture:

> . . . you should at once investigate how it was made, that is with what consequence the forms have been applied. You have to make yourself clear with what talent the volumes concerned are brought in concordance with it. But not only that, you even have to admit also that the proportions have been applied with excellence and the decoration with great understanding and taste. All in all, you have to admit that the whole work shows an absolute entity in all its parts.

Typology

Many people gain the impression that the front fa ade of Berlage's Beurs is more appropriate for a church than anything else. What is an Exchange? Essentially it is a more or less covered or enclosed place where commerce takes place, frequently a sort of market without stalls, a place where people meet with only one aim – business. Until the late nineteenth century they were nothing more than (enclosed) courtyards. In Catalonia the *Llotja* was one of the most important building types in the city. They are identical, a rectangular space surrounded by a thin wall with large window openings and the roof as a collection of opened umbrellas, vaults on pointed arches and spiralled pillars on a square grid, one or two entrances, floor just above street level. That is what exchanges in Barcelona, Valencia, Palma de Mallorca look like. They also display a significant, urban presence.

Berlage thus probably had a clear picture in his mind. The programme for the competition apparently supposed that the term 'beurs' was clear enough by itself. The literature about the Beurs repeatedly testifies to the double function which the building had to meet and which may be found in several locations in the building. The 'other' function (possibly the main function in the mind of Alderman Treub as representative of the local administration) was the provision, for large meetings of those who up until then as a group had been homeless, the labourers (movement), of a socialist manifestation hall, to be paid for by the exchange speculator.

The building mass

The Beurs appears quite massive because two sides and the roof structure can be viewed simultaneously. Seen from the south, omitting for the moment the roofs and towers, the building is one mass of about $140 \times 35 \times 14.25$ metres, having a range of openings. But, though abundant, the openings do not break the massiveness of the building. The other two fa ades have a somewhat different aspect. It becomes evident that Berlage intended the exterior of the building to express the functions, rather than possible 'meanings'. The massiveness is dissolved into small volumes, according to their function, which blend well with the adjacent buildings at the

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northern end. Berlage managed to manipulate the enormous bulk (of the programme) to the surrounding heights of the buildings, the functions and the proportional system.[7]

Proportions and measure

From his presentation drawings for the final project we can deduce how precisely Berlage was, in the end, working. The inserted module lines indicate exactly how the different parts of the building are related to each other and to the whole, and also where the material is going to be placed, for instance with the centre line coinciding with the modular grid. In Berlage's own words: 'The art of building is the art of composing precisely, such that from there on, a building which is not composed precisely, can not be described as a piece of art' (from *Seven lectures on the Art of Building*). Berlage discussed the importance of proportions in a building most extensively in his Zürich lectures, published in 1908, in which he rhetorically asked: 'Would designing on a certain geometrical system not be a great step forward? A method, with which several of the modern Dutch architects already are working?' He had evidently learned a lot during the design process.[8]

Choice of proportional system

There has been much discussion about the basic figure in the fa ades of the Beurs, the so-called Egyptian Triangle with the sides 8 (base) and $\sqrt{41}$ (oblique side) and height 5. Half of this triangle is the square-angled one with base 4 and vertical 5 (proportion 1:1.6). In this triangle the inclination of the one oblique side ($\sqrt{41}$) is important. We know that in the traditional 'grachtenhuis' (canal house) the window panes have a diagonal under ~50° with the horizontal, which corresponds with the angle of the golden section. In Berlage's Beurs this angle is 52°, also rather near to the ideal of the Golden Section with a proportion of 1:1.618 . . . The advantage of Berlage's system of proportion is, of course, that it works with full numbers, 8 and 5, in the two common directions, the horizontal and the vertical (Fig. 7).

On the other hand, Berlage worked with brick and calculated the height and width in courses and headers (so called *koppen*). The measures of the applied Waalformat being 11.2 and 6.25 cm (≙9:5 = 1.8:1). This means that only a multiple of the element can correspond with the Egyptian Triangle. Thus the question remains: how did he do it? It should be mentioned here that he used, vertically, 16 courses per metre and practically 9 headers per metre horizontally.

Berlage was quite clear in his Zürich lectures about his choice of the Egyptian Triangle (for example, p. 60 of *Grundlagen)*. But far less clear is his reason for the basic module measure concerning which he only declared that it resulted after a long search, as the right module (p. 14 of *Grundlagen*). Neither did Berlage make any attempt to explain the double-square in his Beurs ground plan, although the use of it there is obvious.

Notes from historiography

In his *Dictionnaire Raisonné de l'Architecture Fran aise*, Viollet-le-Duc proposes, under Proportion, three possible proportional triangles: '*1) le triangle isocèle rectangle; 2) le triangle que nous*

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appelons isocèle Egyptien; 3) le triangle équilateral' ['1) the isoceles triangle; 2) the triangle known as the Egyptian triangle; 3) the equilateral triangle']. Viollet-le-Duc lends these triangles stability. The equilateral has the disadvantage of an indeterminate ($\sqrt{3}$) proportion between the width and the height of the triangle, unlike the two others. Berlage, probably after painstaking reading of *Proportion*, sought to conform his design to a system of 'symmétrie' = 'proportion', or in the French writer's words '*les rapports entre le tout et les parties, rapports logiques, nécessaires, et tels qu'ils satisfassent en même temps la raison et les yeux*' ['the relationship between all the elements, an essential, logical accord such that it satisfies the eye and the mind'].

In his 9th *Entretien sur l'Architecture*, Viollet-le-Due examines extensively the theory of proportion. He explains the proportion of the Cheops pyramid and what this proportion exhibits, specifically the combination of the decimal and the duo decimal systems. He also suggests that the 'Egyptian triangle', since the building of the pyramids, has been applied many times in architecture, as in the Mosque of Amrou (Cairo, 641) and Amiens Cathedral (1218). The ratio 5:8, he writes (I, 408), satisfies the eye, which is as essential as satisfying reason (*raison*), the eye is not content with equal dimensions, demands difference in height, width and depth, but also, '*par des divisions . . . il facilitait les tracés*' ['through its divisions it facilitates the layout']. Berlage adopted this idea following some research. This research we can read in the diagonals which Berlage added to existing design drawings. While we find at first that these added

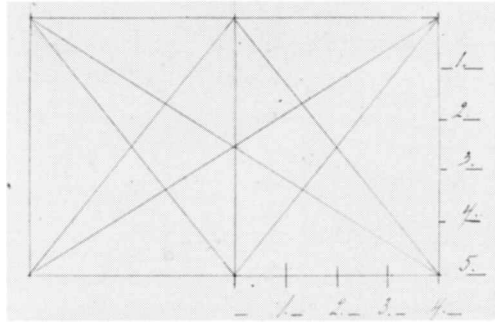


Figure 7.
Diagram of proportions included on the drawing containing cross sections, which constitutes one of the contract documents dated 1898.

lines were drawn over the whole fa ade and even extend from it irregularly, Berlage in his later drawings starts these diagonals from the level of the ground floor while all that is drawn above this level is much more in accord with the system. By then he had made use of specially contrived wooden triangles, as mentioned in his Zürich lectures (Figs. 8, 9, 10 and 11).

Why did Berlage use this ordering system only above the interior floor level and not for the whole fa ade from street level upwards, in other words for all that is visible? Viollet-le-Duc writes that the systems of triangulation in the Middle Ages started from the interior, namely at the top of the column bases: '*La base AB du triangle inférieur ABC repose sur les bases des piliers de la nef, c'est toujours lá le niveau qui sert de point de départ*' ['The base of the lower triangle ABC rests on the base of the pillars in the nave, which always serves as the datum']. He does not explain, sadly, what may have been the reason to start a system of proportion at such a height. Berlage's decision to start from the level of the ground floor makes more sense. Kromhout initiates his system at the same level and

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so did the Catalan architect Antonio Gaudí y Cornet.

Consideration of modules

The longer the span the more versatile the spaces become, but a space may be too big. In the Beurs we witness some wide spans which were not necessary *per se*, but originate in the pre-history of the building. The original exchange as a type existed in large, uncovered, secluded spaces surrounded by small covered offices in a gallery. In its essence the Beurs 'hall' therefore is a covered, secluded space, not a hall. Given the movement of people on the floor, small spans with intervening columns would have been possible, but this was clearly not the wish of Berlage and his clients. On the one hand was the factual programme of the Beurs, covered spaces for large meetings of the growing labourers' movement; on the other there is the example of the Catalan *Llotja*, which has rather modest spans. There are also acoustic consequences in a large space, and this proved to be the case in the Beurs. In Berlage's Beurs (as in the former ones) the spaces around the courtyards are mostly restricted in their dimensions, the narrowest span being 3.80 metres, a quite normal size that can easily be covered by

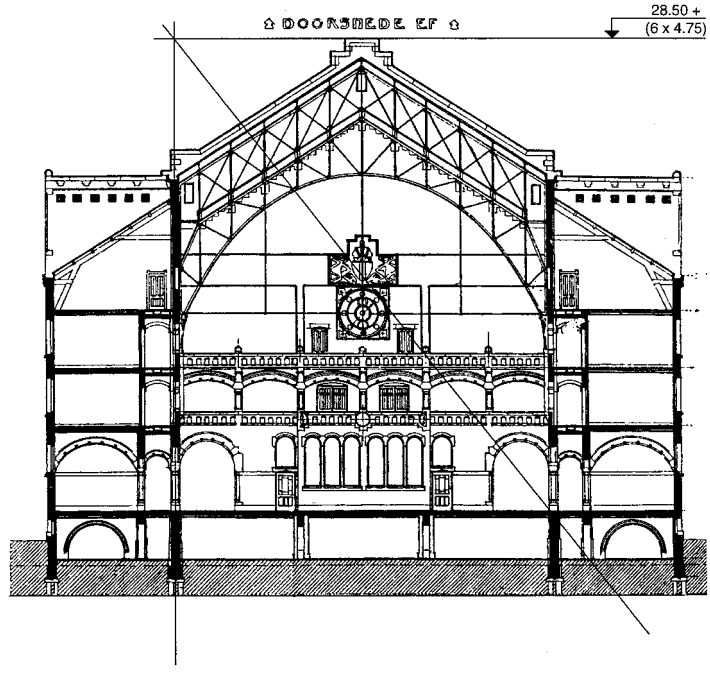


Figure 8. Systemlines over cross section E.-F. of the specification drawings with measures of height in multiples of 2.375 m (summit of fa ade f.i. = 6 × 4.75 m = 27.00 m relates with 6 × 3.80 m = 21.60 m or 0,5 length of main hall).

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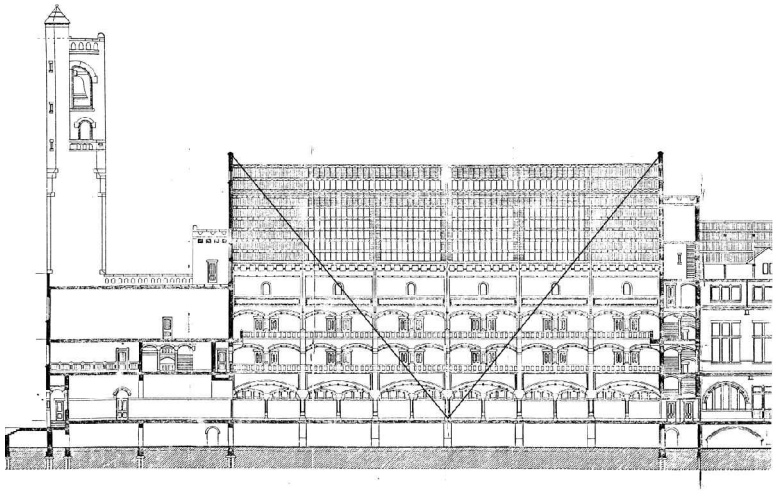


Figure 9. Section through main hall; with schematic lines by author indicating the proportions of the hall 8 : 5 (Author's scheme III).

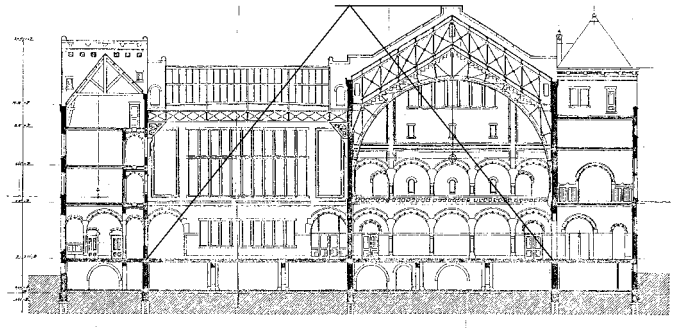


Figure 10. Cross section through the two small halls with schematic lines by author indicating the proportional system (Author's scheme IV).

traditional structures in iron or wood. As the walls are one brick thick, the span of 3.80 metres provides room widths of 3.60, 1.70 and 0.825 metres. From the available sources it is not clear what decided the dimension of 3.80 metres, but all in all the chosen measure turns out to be a logical consequence of rational considerations.

The rectangle 1:2 – the double or super square

In relevant literature, the rectangle 1:2 with a diagonal $\sqrt{5}$ has frequently been identified as ideal for ground plans. August Thiersch, for example, proved in his *Die proportionen in der Architektur in Handbuch der Architektur* (J. Durm a.o., Darmstadt, 1893) that many Greek temples have a ground plan

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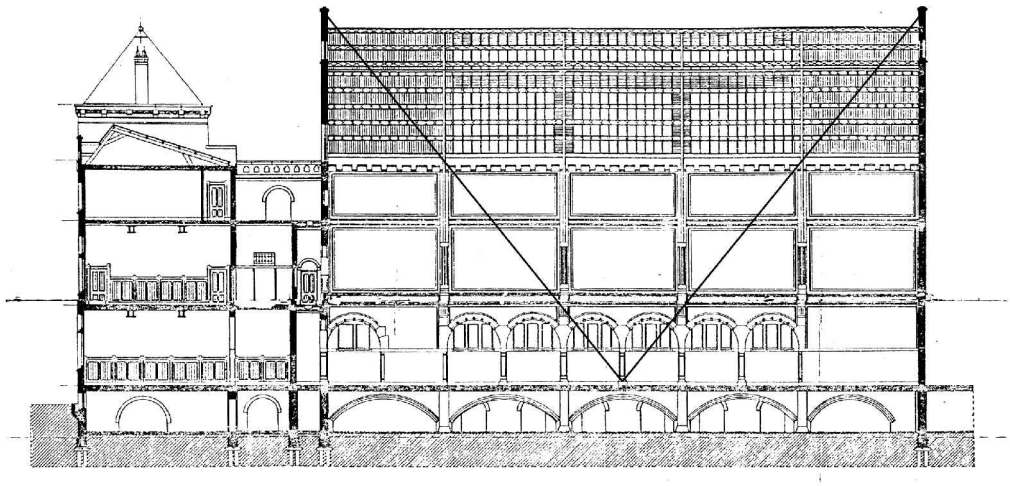


Figure 11. Section through one of the two small halls with lines by the author.

with this ideal proportion. Gaudí also repeatedly used this figure as a basis for his designs, in plan as well as in elevation. Although the Beurs ground plan, because of the given site, has a proportion of (nearly) 1:3, and thus is not a double square, it becomes obvious that Berlage used this basic figure of 1:2 repeatedly for the division of his ground plan. The three main halls all have the proportion 1:2, not including the side aisles; also the two groups of small rooms at each end of the main hall are set in a double square. The northern group of small rooms is an exception, although it forms a square together with the two small exchange halls and their side aisles. Berlage made his choice for the double square between 1896 and 1898, as a comparative analysis of the first design phase and the plans for the building specification confirm (Fig. 12).

Further explanation

While the measures of 190, 380, 237.5 and 475 cm and their multiples can already be found in the specification drawings (Specification nr 18) it is difficult to determine why he used these, and no other, measures. The following considerations probably contributed:

a) the size of the smallest element to be used and of other standards, in our case the brick with Waalformat;
b) repetitive space dimensions in accordance with specified functions;
c) the general dimensions of the available site and their relative proportions, including heights as permitted by regulations.

As already observed, the applied brick in Waalformat does not fit in an Egyptian triangle. The smallest quantity of bricks necessary is 17 headers

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and 19 courses – each prime numbers. The conclusion is simple; Berlage took the smallest 'unit' possible of whole headers and courses, starting from a header measurement of 11.2 cm and course dimension of 6.25 cm, both including the joint, using normal bricklaying methods, the standard of the Waalformat and the practical proportion of 5:8. The courses include a 1 cm joint, the vertical joint being 0.7 cm. 17 headers and 19 courses give 190 and 118.75 cm. The last measure appears rather awkward, but results in exactly 16 courses per 1.00 metre rise, normal bricklaying practice in the Netherlands. The 190 cm is, furthermore, not too difficult to use. In the Golden Section 118.75 cm would mean 192 cm length, while on the other hand 190 cm would give a height of 117.5 cm. Berlage's choice seems to be a rational one.

It is obvious that Berlage introduced a maximum of modules of 3.80 metres on the given site. It also becomes clear, from a comparison with the design of 1896 (ground plan of the first phase) that it was only between 1896 and 1898 that Berlage came to use this strict application of the 3.80×3.80 metre square module, adding the hall module of 1.90 metres for refinements in the plan. This also goes for the introduction of the double square which defined the plan in its ultimate version. By applying the double square Berlage defined the width of the middle part as 6×3.80 metres.

The ground plan of what M. Bock calls the second phase was remodelled on the base of a square module, which resulted in a slight displacement, also because Berlage had obviously decided at the same time to use the double square in plans (and sections) as much as possible. Apart from the already illustrated centre part we find this figure in the main space of the great hall, the two other halls and the part at Beursplein. The depth of the side aisles of the halls was defined at two modules of 3.80 metres, which defines these zones as the sum of double squares.

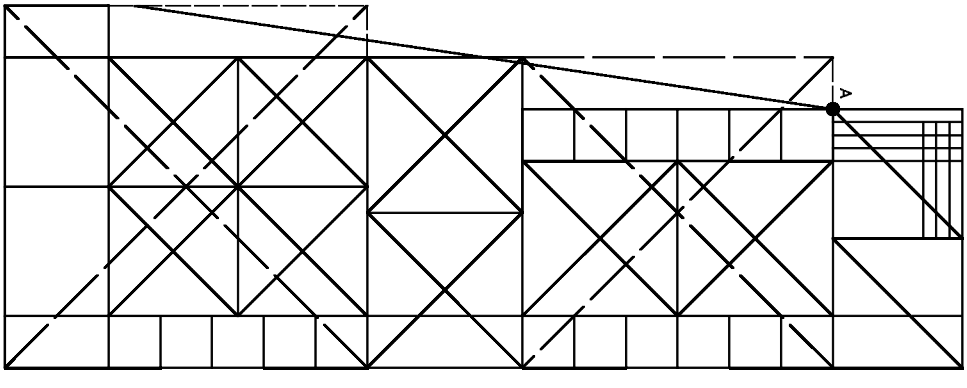


Figure 12. The executed groundplan in squares and double squares (Authors scheme I).

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Apparently Berlage found it of paramount importance to retain the main hall, including the side aisles, untouched. Already in the first design phase, this space fitted precisely within the oblique back side of the building, while in the specification drawing the change in direction on that side coincides exactly with the southern corner of the goods exchange hall. The great hall has become extremely pure, even more so because of the perfect compatibility with the cross section, which is defined exactly by the Egyptian triangle, determined between the external walls and the ridge of the inner glass roof.

This led to the happy circumstance that the main hall could become 10 modules wide (6 + 2 × 2). The length of that room became 2 × 6 = 12 modules. It follows that the middle part is 12 × 6 modules and the two smaller halls constitute 5 × 10 modules each and at each side 2 modules for the side aisles (one for each hall). The northern end of the building has a width of 14 modules and a depth of 4. But here we find that other considerations than proportional doctrine determined Berlage's decision, one aspect being the limits of the site, another the functions to be housed and a third the compositional aspect of the towers.

Beursplein façade

From measuring drawings and reasoning it appears that Berlage used the centre of the (main) tower as the measuring line for its height, a precedent established in other architects' work such as Kromhout's Hotel American (Amsterdam 1898–1900) (Fig. 13). The tower occupies 4 modules in width; the axis of the lower splits the Beursplein fa ade into 2 and 17 modules. From these 17 modules follows the height of the tower: 17 × (190 × 5/4) = 17 × 237.5 = 4037.5 cm (17 vertical modules). It is notable that Berlage chose to use the prime numbers 17 and 19 on a grand scale and that this has not been previously established and described. On the Damrak side, the height of the tower does not have an obvious, clear proportion with the fa ade, which may indicate the importance and the character that Berlage gave to each of the fa ades. On the other hand, in the centre of the Damrak fa ade we find the Egyptian triangle starting from the axes of the two towers of the middle section at floor level and their apex: *10 modules of 190 cm correspond with 10 × 237.5 cm* = 23.75 metres in height. The gutter level at Damrak, 6 × 237.5 cm, corresponds with 6 modules, which is a 1.5 'canalhouse' of which 6 fit in the major hall and 5 in the small ones. It follows that the large hall plays the most important role in defining the height of the Damrak fa ade, although the building regulations may also have had a significant influence.

Material composition

Bearing elements

The major bearing element of the Beurs is the massive brick wall. Berlage's master work was, thus, still substantially traditional after a half-century history of iron and steel structure development. The whole exterior of the Beurs, including the massive tower and all interior walls, were built with this most Dutch of materials. The walls, in reality very slender, are two, one, or half a brick thick and look very slim indeed in the sections of the building. The thicker walls (43.4 cm), from which one expects solidity and

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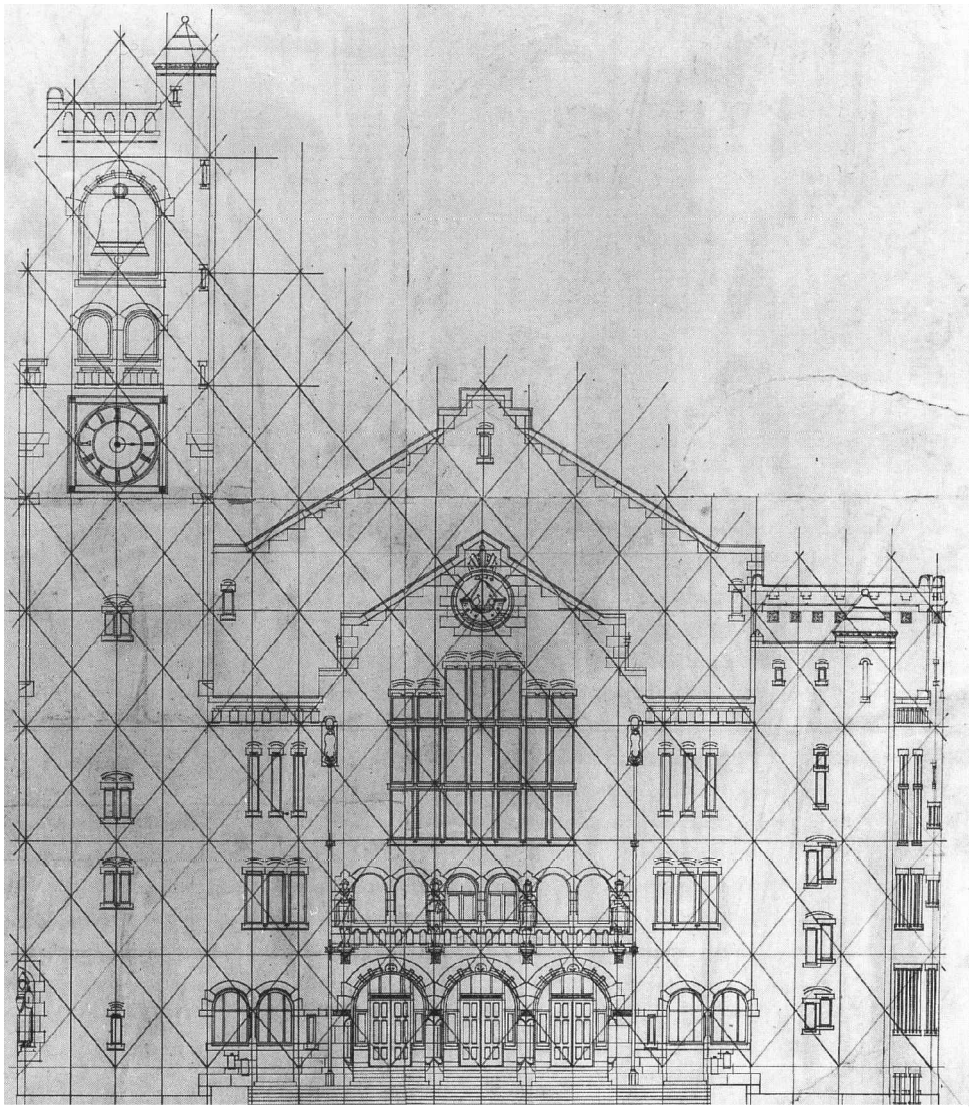


Figure 13. Fa ade at Beursplein as published in 1898 (Author's scheme V).

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stability are, furthermore, highly perforated, particularly at those points where, due to increased vertical or horizontal loads, there should be a concentration of, or stronger, material. This airiness does not apply to the corner towers at Beursplein, which have a visual intensity, although there, also, the walls are thinner than would seem necessary to work as counterweight for the 'nave', as in many gothic churches. The arches in the brickwork, furthermore, seldom have the optimal form that would result from the loads they are intended to transmit either internally or externally. Courageous? Genial, bold *Formwillen*, or the result of ignorance?

From the repair history of the Beurs after 1904 one might conclude that it is the latter. Much has been written about Berlage's quest for 'purity' and 'rest' in his work.[9] This quest became apparent in the gradual decrease in variation of form during the design process, the fewer forms the better it became. The purer result also transpired given fewer 'hidden' materials and, also, the 'right' material in the right place, meaning brickwork in the planes, including the arches, and stone as the stronger material in compression in locations where forces concentrate such as the springing of the arches where the forces are gathered and descend through the columns to the piled foundations. However the transition from brick to stone is very abrupt, which must result in either overloading the brickwork or under stressing the stone.

Berlage may imply rational procedures, but he did not always achieve that result. It is more instructive to see the Beurs as a kind of laboratory, a building in which research was continuously conducted, in the preparatory processes as well as during the construction itself.[10]

The documents of the committee which reported on the condition of the Beurs in 1906 make very clear that the building as a whole was poorly structured, although their proposals did not, in the end, improve the structure.[11] These proposals were intended to stiffen the building where they considered it to be necessary. But this was of little use since the foundation consisted of wooden piles which were only interconnected by means of a flexible wooden framework on which the brickwork of the walls is supported, and consequently lacks the stiffness of more stable subsoil conditions. To avoid cracks caused by movement of the foundations would require a more rigid substructure but, if this is not possible, then it would be better to make the building itself flexible in order to adjust to the subterranean conditions. Such was the case with traditional buildings, where the lime mortar of the brickwork allowed certain deformation without the danger of cracking. The report on the Beurs is striking in its unscientific approach although calculations of the trusses to be found in the report are, related to today's standards, surprisingly adequate. One may conjecture whether the architects on the committee had better insight into constructional and structural matters than Berlage. Their proposals would, however, have compromised the spatial and, in many places also, the material qualities of the building. One only has to consider the concrete beams, as suggested by the researchers, appearing in a building which conceptually was a traditional structure of wood, brick and stone.

On the other hand it is striking that more than 25 years after the publication of the graphostatical method of Cremona, which had made possible the

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calculation and determination of any form in any material, this system had not been applied by Berlage. It appears he obstinately negated the logic of such methods, making forms and structures which were more expressive of the idea of rationality than the result of rational processes. At the same time that Antonio Gaudí y Cornet (1852–1926) was able to build his arches and vaults by understanding and applying the most advanced methods of structural analysis with models, Berlage was so absorbed by the idea of simplified form, of bringing the building to rest, that there was no place for a scientific method of form-finding such as Gaudí employed to resolve the static forces organically. The fact that we find few problems of cracking in Gaudí's work is as much symbolic as revealing in comparing the work of the two masters.

The trusses

It was in the Beurs where Berlage had, for the first time, the chance to find a solution for the covering of large spaces (Figs. 14, 15 and 16). The goods exchange, the largest of the courtyards to be covered, and the stock exchange, received a saddle roof on trusses while the corn exchange was covered with a row of industrial lights on straight, composed iron rafters. These rafters have one continuous height, which means that the general form does not literally express the loads of the roof lights nor on what structural principle the trusses are supported at each end on the open-work metal brackets. The two other halls display a completely different solution, in which the general form and the parts express much more clearly the desired tracery of forces through dimension, position and direction. It is here perhaps, that Berlage has experimented and developed most. But how advanced was this construction and how logical? And was it the work of Berlage himself or his structural engineer J.J.L. Bourdrez?[12] The calm, which Berlage undoubtedly strove for in the Beurs, is weakened not only by the emphatic presence of trusses having a very specific form but also by the way they plunge between the walls.[13]

The protruding tooth-like cornice where the walls terminate is brought down locally in a strange way, while the brackets on which the trusses rest give the same feeling. The originally conceived desired image was clearly different. The perspective drawing of the main hall shows that the trusses were thought to be maximally transparent, thanks to the application of long tension rods. The trusses dissolve against the plane of the glass roof and the upper parts of the side walls. The brackets, also, are more integrated into the plane of the wall. The elements of the trusses are restful, all parts in tension having the same section like all components in compression. Why then, if Berlage wanted 'rest', did he change the roof structure for one that is much more assertive? The origin of such an important change is not known. It may be related to the new knowledge and insight into steel structures; the absence of tension rods between the ends of the span seems to indicate such an influence. Yet tension rods had to be added rather soon after completion of the building, which fact gave the construction a remarkable ambiguity. And, curiously enough, they still appeared immediately before the trusses were put into production. Tension rods were proposed in the competition project of 1885, as can be seen in the

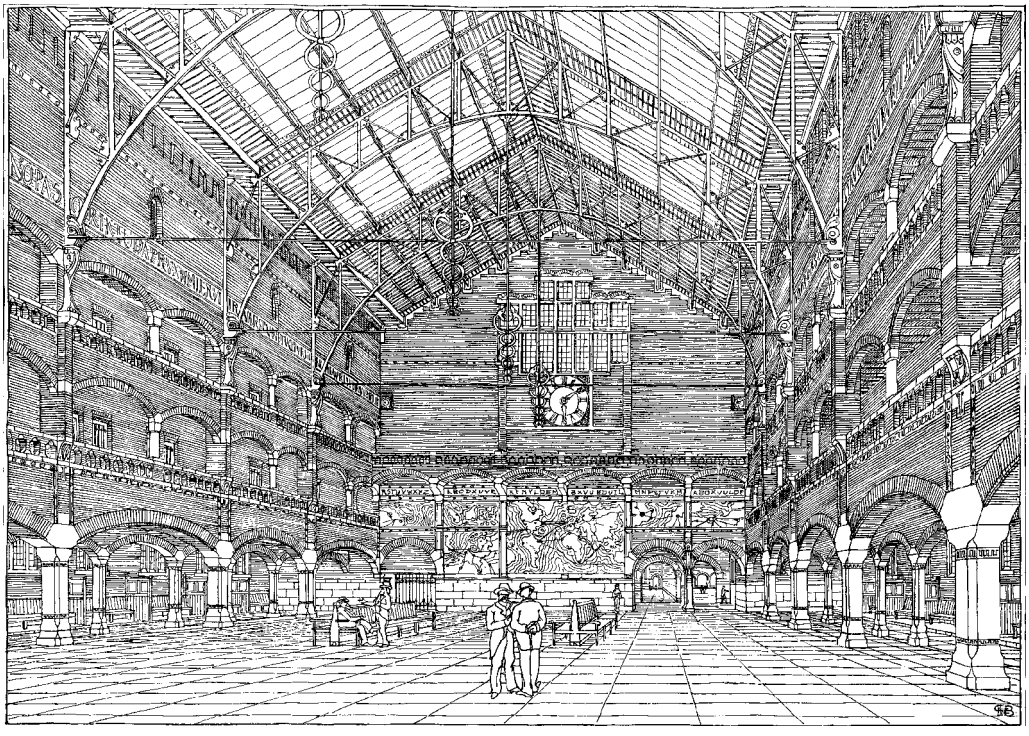


Figure 14. The goods exchange seen towards the other two courtyards. Perspective pertaining to the specification drawings for bids, 1898.

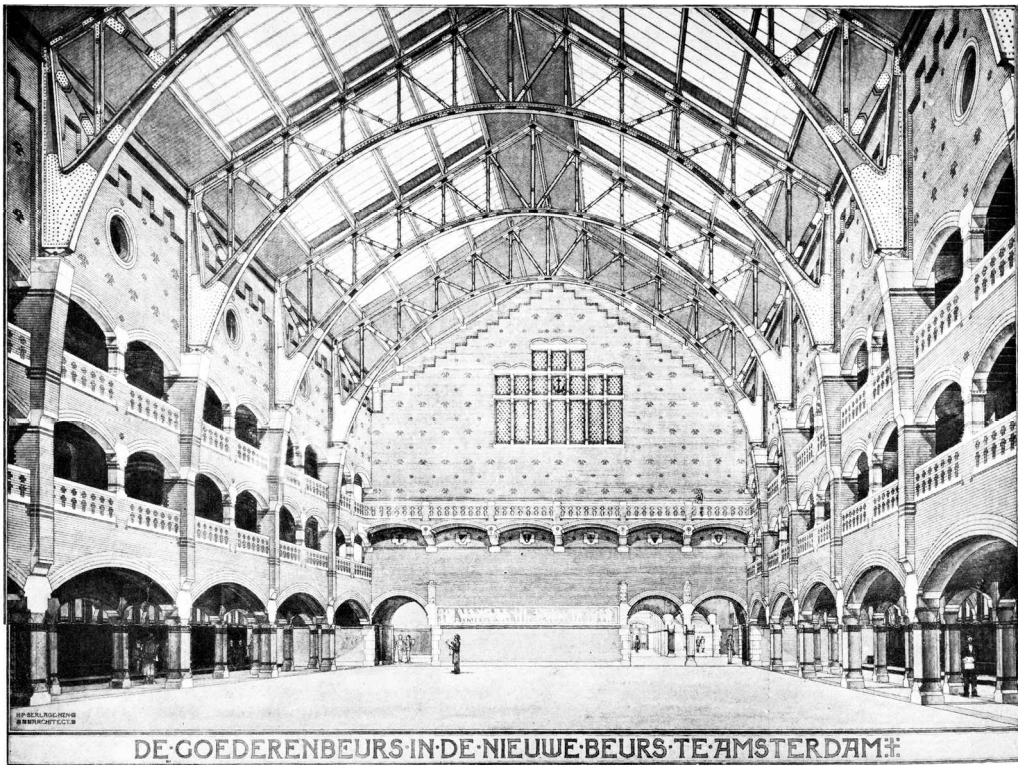


Figure 15. The goods exchange seen towards the other two courtyards. Perspective pertaining to presentational drawings by H.J.M. Walenkamp in 'de Architect', 1901.

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Figure 16. The goods exchange seen in the same direction during erection of the spans. Photograph taken by P. Oosterhuis. (Source: Begemann archief in Helmond City archive.)

perspective of the main hall, but this was several years before the commission was awarded to Berlage. They were accepted as a necessary means to support the building, and more specifically the roof surface, and symbolised the rationality of the architect and his production. Reflecting on the problem of the tension rod in the great hall one must admit that Berlage had, seemingly, developed a better eye for a restful image than for resolution of static forces. This must also have been the conclusion of the Committee which, quite soon after the building had been inaugurated, commented on the failures that had become obvious, such as severe cracking of the walls and displacement of the trusses.

One should call attention to the presence of Pierre Cuijpers in this committee, of significance because of a notable oversight by the biographers

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of Berlage and his Exchange building, the obvious identity of the trusses we are discussing here with those which had been designed for the courtyards of Cuijper's Rijksmuseum between 1877 and 1885, many years before Berlage completed his definitive design for the Beurs. In fact, the realised trusses look even more like those for the National Museum (Fig. 17) than the ones which were presented by Berlage for the building. This is even more significant since the form of these trusses is not very usual. I know of only very few look-alikes, one being the enormous spans for the Halle des Machines in the Paris World Exhibition of 1888.

The main question concerning the realised trusses is why did Berlage decide to use trusses without tension rods when he started to build the covering of the courtyards? Before answering that question a few differences with the Cuijpers solution should be noted. First of all we see that Berlage left out non-bearing elements, like the decoration at the feet of the trusses. His 'decorum' exists in the form resulting from the expected load and in the emphasis placed on the functional elements, like the rivets and the gusset plates, by bright colours. Furthermore Berlage used hinges at both ends of the truss, while Cuijpers tied the feet to the bearing wall. Interesting to note also is the double roof of the Beurs, with which Berlage managed to solve the physical problems that would result from a single-sheet roof as in the Cuijpers solution.

A further discovery

Because many original documents have disappeared it remains impossible to answer questions about changes in the roof construction at the time of erecting the building. The Berlage archive in the Nederlands Architectuurinstituut does not contain the necessary material but some relevant material was located in the City Archive of Helmond, the archive of the once Helmond-based construction firm Begemann which manufactured the iron work for the Beurs. The most interesting items in the archive are the letters sent by J.J.L. Bourdrez, civil and building engineer in Breda, to the Begemann firm between January 1897 and mid-1900. It becomes obvious from these letters that Bourdrez was the consulting engineer responsible for the building specification concerned with the iron work and possibly for other parts where the specification is concerned with structural elements. Curiously enough this was not reflected in the work of the Committee which investigated the structural failures of the building in 1906. Bourdrez writes on January 11, 1899 to Begemann: '. . . as I wrote in the building specification . . .' thus declaring himself author of at least those items in that specification which dealt with the trusses.

This indicates that Bourdrez was already responsible for the trusses as they appear in the working drawings and as published in April 1898. Berlage had explained these drawings during his Beurs lecture on April 1, 1898 to a group of colleagues and other members of Architectura et Amicitia and the so-called Maatschappij ter bevordering van de Bouwkunst.[14]

One of those present must have been Bourdrez, who had become a member of A et A on June 1, 1897. This was just over a month after Berlage had joined on 25th April. Three weeks after Berlage

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gave his lecture it was Bourdrez who took the floor and spoke about 'Yzeren Daken' (iron roofs). Perhaps it was Berlage who introduced Bourdrez to A et A after inviting him to become the engineer for the Beurs.[15]

Berlage published his first sketches for the Beurs in October 1896. By the end of that year he got the green light from the City Council and in March 1898 he had the specification ready for bids. In April Berlage and Bourdrez gave their lectures and on May 9 the bids were received.

When Berlage emphasised in his lecture the perfect collaboration between the architect and the engineer, he most probably had Bourdrez in mind. But neither mentioned his partner in their subsequent lectures nor, more precisely, are their names given in the publications. Yet both must have been happy with the results. Before the Begemann firm started manufacture, in the winter of 1898–9, Berlage and Bourdrez had changed their minds, omitting the proposed tension rods and altering the form of the spans. Thus the changes must have occurred between receiving the bids and the start of the manufacture of the trusses between early May and the end of December 1898. It has not been possible to find direct correspondence between Berlage and Bourdrez nor any other material that might give an answer to the question of when and why the two changed the design. From the Bourdrez letters and from blueprints which were returned by Begemann to the building office it may inferred that after January 11, when the first letter was sent from the city of Breda by Bourdrez to Begemann in Helmond, only minor changes took place. Even though Begemann was afraid that the

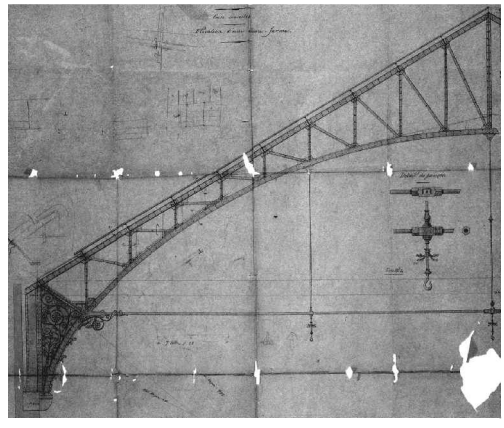


Figure 17. Truss for the courtyards of the National Museum ('Rijksmuseum'), Amsterdam 1877–1885. Architect Pierre Cuijpers.

trusses would need reinforcement during the erection, Bourdrez refused to change them. The form that Berlage and Bourdrez gave to the trusses, together with the new dimensions, must have been a precious thing for them of which they were proud. Only the letter that Bourdrez sent on March 9, 1899 mentions a change in truss A: 'Tomorrow the revised truss A will be sent to Mr Berlage for approval – I may bring it next Sunday for discussion'.

But Bourdrez does not explain what the revision entailed. Neither is it clear who proposed the change. Bourdrez must have been confident of his modern calculations, based on the newest methods, which he had mentioned and explained in his lecture. But according to calculations by the Inspection Committee in 1906 Bourdrez had made mistakes with quite disastrous consequences. One detail in the building specification throws some light on this episode. In the description of the four different trusses, the writer calls those for the

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passage between the halls (D) stijve spanten (stiff trusses), which implies that the others (A in the main hall and B and C in the smaller ones) were not stiff. Therefore A and B needed tension rods, which afterwards were left out while, as mentioned above, the detailing of trusses changed fundamentally. Also, truss D in itself shows a construction which seems to predict the final form of the A and B trusses and which form provides stiffness (Figs. 18 and 19).[16]

The Inspection Committee of 1906 calculated the spreading of the feet of the trusses under full load as being too big for the rolling space provided on the brackets (Fig. 20). This implies that the Committee was right, Bourdrez must have miscalculated. On the other hand, the inclination of the walls, which must have occurred once the building had been finished (and which was established by the Committee), were such that even if Bourdrez's calculations were correct, problems would have arisen. The Committee neglected to analyse the cause of the inclinations which occurred on both sides. I contend it is precisely in those walls that we find the origin of the whole problem. Even if the trusses were stiff enough, and this I believe, with Bourdrez, to be the case, problems would have arisen. The Committee calculated the outward movement (starting from the proposition that the arches rested on one hinge and one roller instead of two hinges, which in itself was a wrong supposition), but it seems that they overlooked the influence the vertical vector of the load of the trusses on the corbelled wall brackets was going to exercise on the walls, or rather on the bearing plates in the 'wall'. The problem is the insufficient thickness of those walls. The responsibility of the engineer did not, it seems, include the non-iron parts of the building which were not included in the calculations. The rationale of the newly developed theories did not yet include traditional materials and structures. In examining the Beurs one understands that Berlage lacked insight into those problems which, simultaneously, were being resolved in the structures of Antonio Gaudí in Catalonia. Examination of the section reveals the weakness of the whole.

Materials and their application

Brick, stone and iron are the most striking materials in the Beurs apart from unpainted wood and tile work. Generally speaking Berlage represents the mass of the people in the brick planes, puts the natural stone in such places where forces are bound together and represents in the iron trusses the progression of mankind. But he also demonstrates honesty in leaving material uncovered or untreated to show its natural origin, such as wood, and truth in the application of so-called ignoble materials without hiding them, like industrial iron. Was Berlage, in so doing, being modern and progressive or was he revealing his own conservatism when building the Beurs? In his publications a few years later Berlage mentions that he himself at 'the Congress in Madrid' (international meeting of architects in 1904) had spoken about the failure of iron as the originator of a new style. This was soon after the Beurs had been opened to the users and the public. Although Berlage makes clear that the inflammability of the material was the main origin of the failure (fire regulations later on

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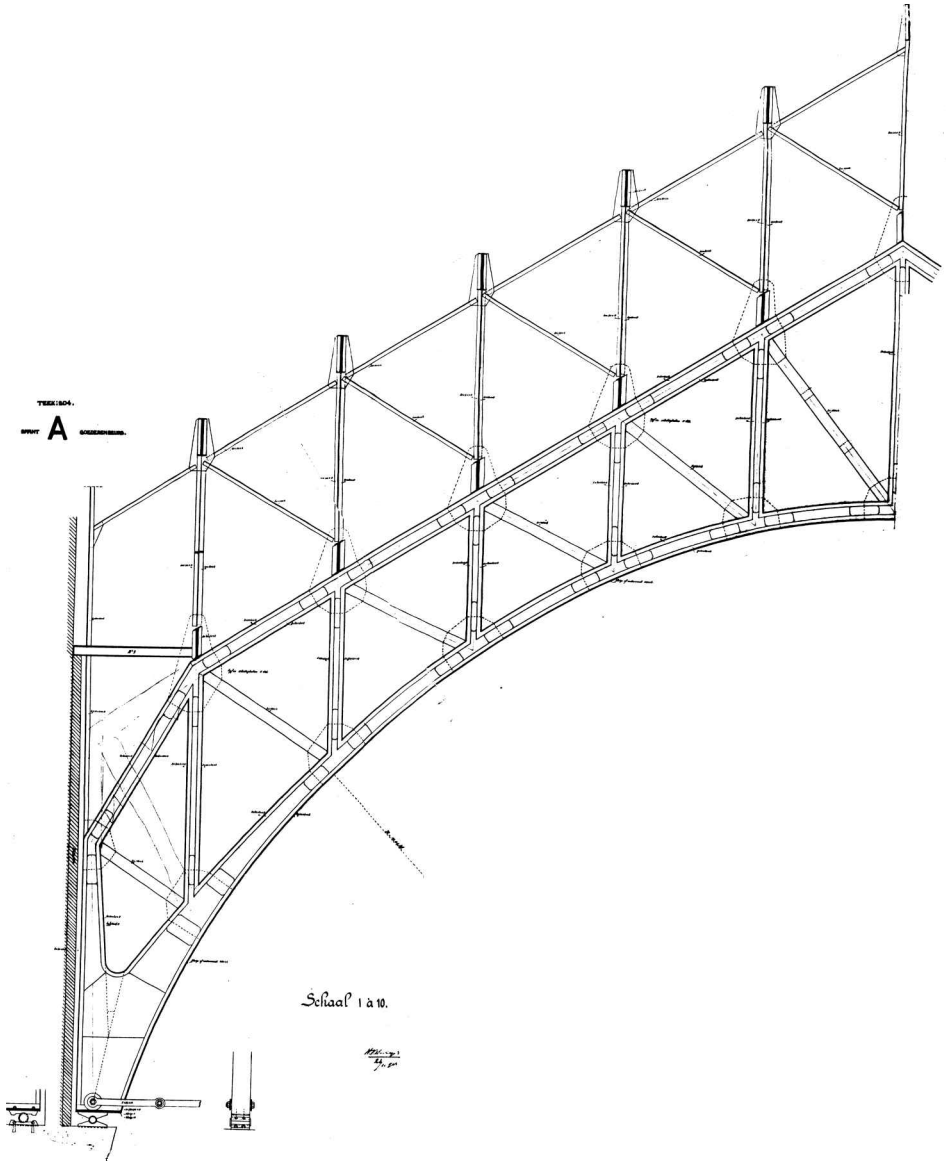


Figure 18. Truss A for goods exchange, with tension rod! Working drawing 204 with sketchy lines that show the definite form. Signed by Berlage on 23.11.98. (Source: Amsterdam, *Gemeente archief*).

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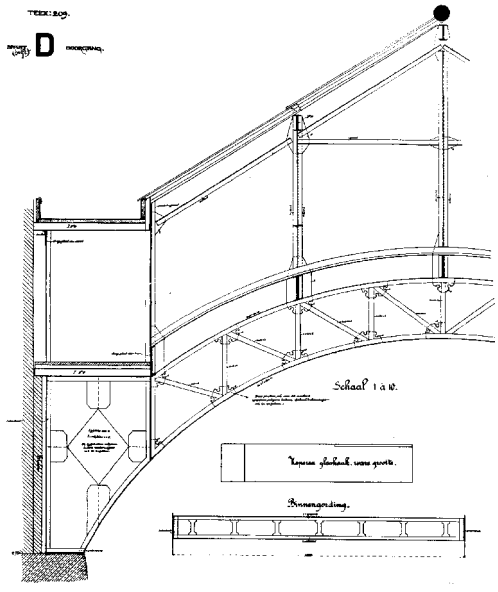


Figure 19. Working drawing 209 showing half of truss D. Signed by Berlage on 23.11.98. (Source: Amsterdam, *Gemeente archief*).

required the material to be covered and thus made invisible) he at the same time declares that it was also an aesthetic failure, 'when they tried to use it in that combination for which it seemed to be the right one, namely in relation with stone.' (Brick in Dutch is called backsteen = baked stone.) This seems somewhat to contradict what we find in the Beurs and what we admire so much, the bold combination of iron, brick and stone as the major bearing materials. Yet Berlage continues '. . . iron and stone are of too different characters to combine harmonically.' Even more striking is that '. . . iron in general lacks the quality of rest, which only a certain mass is able to procure . . .' (Fig. 21).

Although reinforced concrete had already been developed for some time, Berlage did not employ it in his building, even in such places where it would have been invisible, which may be due to his aspiration for honesty. Otherwise it is not easy to understand why he did not use this modern and up-to-date material, where it would have been feasible, such as in the spans for the hall, even more so given Berlage's objections to the use of iron at the Madrid Congress and what he said in the same speech about reinforced concrete in his conclusion: 'As a result of the great advantages of reinforced concrete there exists the probability that we are standing on the threshold of a totally new architectonic era, in which this material will be the actual application, which makes the study of the art form already more demanding.' We can only conclude that Berlage was altogether not very happy with the solutions in his Exchange building. In 1911 E. von Mecenseffy wrote in his book on reinforced concrete (Eisenbeton), when he compares steel (iron) and (reinforced) concrete, that even Berlage with the spatial creations in his Beurs did not manage to overcome the problem that, in general, metallic spans were not yet artistically appreciated.[17]

Bond, brick dimensions and proportional system

In a well-detailed building there exists a coherence between the applied dimensions and proportions and the choice of materials. Berlage wrote: 'The art of building is the art of pure composing', and Viollet-le-Duc: '*les rapports entre le tout et les parties . . . satisfassent en même temps la raison et les yeux*'. In principal locations Berlage applied three materials which co-determined the dimensions of the building,

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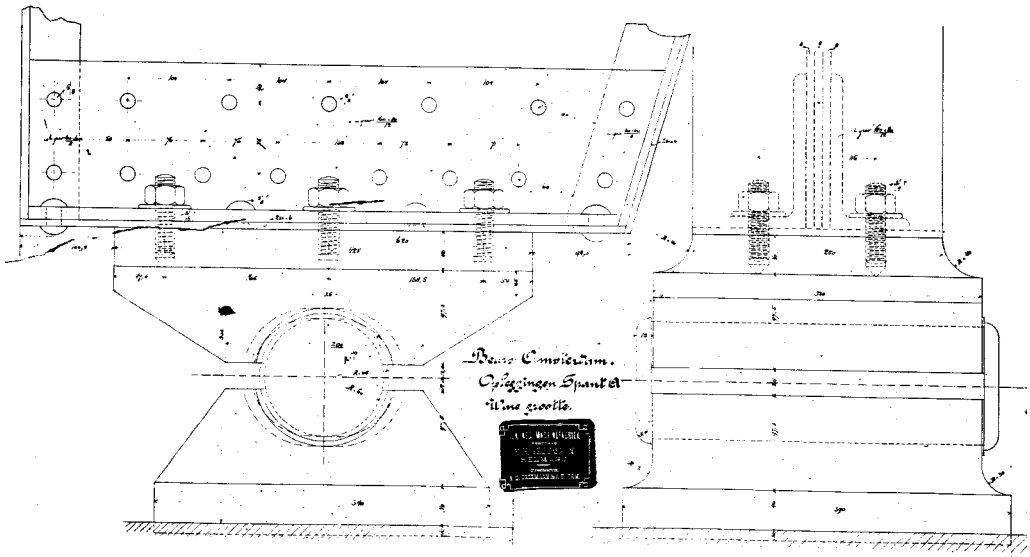


Figure 20. Detail of foot of truss A without tension rod, as drawn for (or by) Begemann firm; date unknown. (Source: Amsterdam, *Gemeente archief*.)

iron, stone and brick, the latter being the only component with standard production sizes. Although the immense amount of brick in the Beurs would have made possible a specific standard, Berlage applied an existing one the Waalformat, the most robust format that the Dutch brick industry was able to produce. It is not by chance that the Waal brick has a basic proportion of 1:2, the measurements being 5.25 × 10.5 × 21.5 cm, which makes it suitable for one of the triangles which Viollet-le-Duc indicated as proportionally correct – *the equilateral, right-angled*. But it did not, therefore, co-ordinate with the Egyptian triangle which Berlage seemed to prefer. A brick with such proportions would be difficult to set in a bond, this in contrast with, for example, the applied Waal brick. The simplest bond would be the *running* (stretcher) bond, but Berlage used a less visually dull cross bond in which, at terminations and corners, he could use the so-called *drieklezoor* (a three-quarters stretcher) and improve the strength of the wall (Fig. 22). But also the bond that Berlage chose to apply has its restrictions. Parts of walls, as between windows, required odd numbers of headers which resulted in a different (symmetrical) termination pattern from those of even numbers: a-symmetrical and

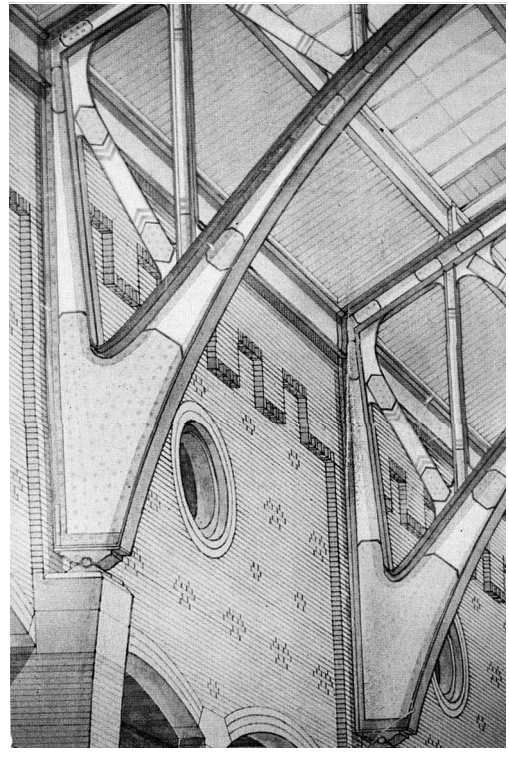


Figure 21. Feet of trusses A over goods exchange. (Publication drawing in *de Architect*, 1901 by H.J.M. Walenkamp.)

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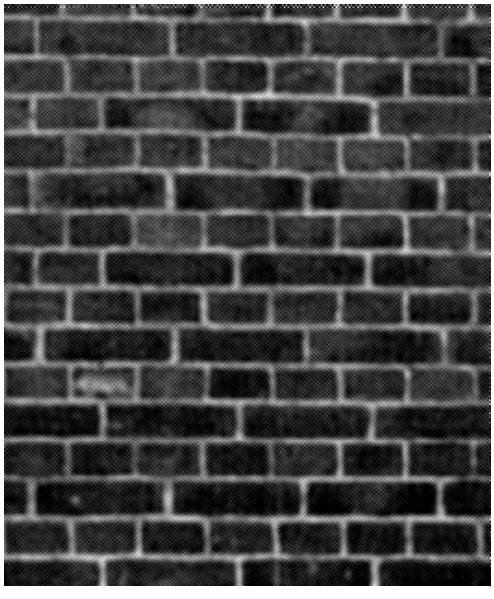


Figure 22. Brick work with proportional systems 17 headers – 19 courses = 8 : 5 (Author's scheme).

therefore unquiet. As Berlage aimed at quietness we may suppose that he had a preference for the first solution and therefore made wall sections between windows with odd numbers of headers. The general module of 17 is thus correct, but the wall part referred to is 34 headers with 20 headers for window openings and 14 between windows at the main floor, both even numbers. Contrary to the theory, Berlage includes the necessary three-quarters in the course of headers, sometimes he even uses quarters, again quite against the rules. We can recognise the principle that Berlage followed in the corners of the building; there one can see the course of headers in one fa ade passing into the course of stretchers of the other.

The aftermath

In 1906 a major investigation was executed by a group of celebrated architects and professors of Delft Polytechnic, concerning serious defects in the building's construction. The Committee seems to have wanted to save the architect in spite of the serious problems that had arisen in the very short period of the Beurs' existence. On the other hand, some of the conclusions of the report are, to say the least, a bit weird. It is necessary to take into account the state of technical knowledge and the theories of the day. Most surprising is the absence of a discussion between the architect and his engineer and the Committee. Of special interest is what the Committee concludes about the deformation of the trusses in the great hall. The Committee calculated a horizontal deformation at the root of the trusses in tenths of millimetres which displays both their theoretical precision and their lack of practical insight. Already the lifting of the complete truss from the floor of the hall to its final position required more freedom of movement between the walls than the few centimetres that the Committee calculated for the horizontal deformation under the pressure of the loads once the whole construction had been completed. There is no written evidence concerning the inaccuracy of Berlage's calculations.

This discussion is still relevant and would provide useful insights; for the purposes of this paper only very general remarks can be offered. The building contains some bold constructional concepts in the first place due to the underground conditions of the site as discussed above. The Committee first comments that the structure would be adequate on compact sand, which is not to be found in

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muddy Holland. Secondly, the Committee explains it is illogical to distribute the functions in such a way that the larger open spaces are located in the lower levels and the smaller rooms above, which is the opposite of what is desirable for optimum stability. It is indeed remarkable how unstable the construction appears to be on each side of the great hall at ground floor level. Further detailed consideration of the trusses of the Beurs is required before a definitive assessment can be offered about the architect and his engineer. The trusses as built have a clearly expressed visual contribution as well as fulfilling a structural necessity. The Beurs should be viewed as a laboratory in which a whole range of experiments led to new solutions several of which failed. This does not mean that the leaders of that laboratory were misguided; on the contrary, if we wish to reveal the secret of the Beurs it is necessary to start from the proposition that, highly intelligent as they undoubtedly were, they knew very well all along what they wanted.

Conclusion

A prime question which remains is, what was the influence of the collaborators on Berlage such as J.J.L. Bourdrez and R. Lambeek? Whereas Berlage was without doubt the nominated architect responsible for the project and its realisation, Bourdrez must have been the designer of the realised iron components which became one of the major features of the building. A further highly important aspect is the proportional system. Who introduced the system? Berlage was late in applying the 'Egyptian triangle' and the 'double square'. Several architects, such as De Bazel were ahead of him. The design sketches and drawings do not show any trace of a systematic application of the two mentioned figures until sometime during the spring of 1897. This was about the moment when, on 15 May 1897, Johannes Balthazar Lambeek came to live on the premises and work there as the main representative (Hoofdopzichter) of the architect. By then Lambeek had already designed and published some personal work in the periodical *Architectura*, of which he was an editor. He may have been responsible for the translation and publication of two of Viollet-le-Duc's *Entretiens*, one of these dealing with proportional systems, amongst which is the 'Egyptian triangle'. The article was signed J.L. . . .[18]

Figure 22. Brick work with proportional systems 17 headers – 19 courses = 8 : 5 (Author's scheme).

Notes and references

1. Pieter Singelenberg, *H. P. Berlage Idea and Style, the quest for modern architecture*, Utrecht, 1972.
   For an extensive bibliography see Wessel Reinink, *Amsterdam and Berlage's Exchange*, (Contemporary Criticism, 's-Gravenhage, 1975). Manfred Bock *Anffänge Einer Neuen Architektur*.
   For Berlage's own publications see specifically his *Studies over Bouwkunst, Stijl en Samenleving* (Rotterdam 1910 and 1922), especially *Over de waarschijnlijke ontwikkeling der Architektuur*, and also *Grundlagen und Entwicklung der Architektur* (Rotterdam, 1908).
   For the competitions for a new Exchange building in the 1880s see *H. P. Berlage 1856–1934 een bouwmeester en zijn tijd Bussum, 1975*, p. 277 etc, in *Netherlands Yearbook for History of Art*.
   All of Berlage's own texts have been translated into English and published by the Getty Foundation.
2. The Central Station, by Pierre Cuijpers was built in 1885 on new-raised land in the Y river precisely where

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the Amstel river flowed into it (and has been much criticised for that reason to this day, as it blocks the view from the city to the harbour). Remarkably enough the station complex has not suffered from the problems of having been built on a comparable site to the Beurs.

3. We must take into consideration that in the nineteenth century the city limits generally did not include much open space, which meant that annexation of neighbouring agricultural communities had to take place to make enlargement of the city possible.
4. Ever since discussions about the replacement of the Zocher Exchange, built in 1840–45 by Jan D. Zocher jr., had taken place, many different sites had been proposed at least from the first round of the competition onwards. Since they are not relevant here, I only want to mention Wessel Reinink's *Amsterdam and Berlage's Exchange*, (Contemporary Criticism, s-Gravenhage, 1975): also for the history of the Commission.
5. Lecture held at the request of his colleagues, Jeroen Schilt and Jouke van der Werf, *Genootschap Architectura et Amicitia,* (Rotterdam, 1992).
   Also Architectura, *organ v. h. Genootschap Architectura et Amicitia* (magazine) Amsterdam, 1898 and *Bouwkundig Weekblad, organ van de Maatschappij tot bevordering der bouwkunst* (magazine) (Amsterdam, 1898).
   These periodicals and De Opmerker are the main contemporary publications on the Beurs.
6. The Dam square itself was named after the old dam in the river Amstel, the origin of Amsterdam or Aemstelredam, founded in the thirteenth century.
7. The distance 33.00 m., foreseen in the site drawing for the competition, between the building and the 'nieuwe te maken bekledingsmuur' (the new covering wall for the water side) does not exist in reality, as can easily be seen when visiting the site.
8. Sergio Polano *Hendrik Petrus Berlage, het complete werk* from the Italian *Opera Completa* (Milano, 1987), *Thoughts on Style, 1886–1909*, Getty Research Institute for the History of Art and Humanities, 1996.
9. *Tekeningen Disegni Hendrik Petrus Berlage* (Catalogue, Biennale di Venezia, 1986).
10. This is not the only example of an architect as experimenter of course. There is more experiment– so decisive for the built form – than is usually acknowledged. The famous Zonnestraal complex by Duiker (Bijvoet) and Wiebenga turned out to be, in an analysis conducted by Hubert Jan Henket and Wessel de Jonge in the 1980s, one long series of experimental constructions, in which the architect-engineers were continuously inventing static and physical solutions for the problems to which they had to respond.
11. *Rapport betreffende het onderzoek naar den toestand der Koopmans Beurs te Amsterdam* (Amsterdam, 1906). Two parts and appendices, such as calculations and recommendations.
12. The Begemann firm archive contains the letters that J.J.L. Bourdrez sent to Begemann from Breda, where from September 1898 to Summer 1900 he ran a private office and held a position as teacher at the KMA, the Royal Military Academy. The letters are numbered from which it becomes clear that several of them are missing. Therefore – and because there are no letters by the Begemann firm to Bourdrez or Berlage – it becomes impossible to know what precisely happened and who was responsible for what. In 1900 he started to work as the principal engineer for the railway from Rotterdam to S2215cheveningen (The Hague), being responsible for all major structures for this line (Obituary in De Ingenieur, 1924). It is unclear whether Bourdrez worked for Berlage in his municipal office or as an independent engineer.
13. In itself it was a difficult and very precise manoeuvre to place the trusses between the already finished

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walls, as may be seen from photographs taken during the construction works.

14. The set of drawings were presented at the annual 'Tentoonstelling van Bouwkunst' from April 27–May 26 in the club building of the Maatschappij at Marnixstraat 402 (nowadays the Nieuwe De La Martheater right behind Kromhout's Hotel American). The drawings had to be sent in before April 13. The exhibition was dedicated to the coronation of Queen Wilhelmina.
15. See Architectura et Amicitia (Note 5).
16. C is a different kind of span, a horizontal truss.
17. The analysis by Viollet-le-Duc (and probably Semper?) is only partly right. The 'gothic' did not exist as one style, one system, one structure. The common denominator, the essence of 'the' gothic, is the search for and finding of a different way of building, one that demands rather less material for larger envelopes of spaces. As such the gothic still exists in our days. It furthermore must have been of influence that the greater demand for permanent structures made it necessary to import materials along longer transport lines to develop new materials. At the same time there is the wish for exclusiveness in a society of abundance. These are factors that played a role in the project for the Beurs.
18. The architectural historian Marty Bax supplied me with a copy of her article in *Jong Holland* (1990,4, notes 10–12), in which she claims that J. B. Lambeek, JBzn, was the translator of the *Entretiens* and not, for instance, J. M. Lauweriks, also an editor of the same journal at the same time as Lambeek. But there is no proof; it could well be the founder of A et A., J. Lelieman, retired architect at that time and thus probably with a larger knowledge than young Lambeek. Also, some confusion is possible concerning the family name Lambeek. The Lambeek who came to work for Berlage was certainly not the one that Bax chose from the Amsterdam archives. That one, with the same names Johannes Balthazar was born in 1877 and notwithstanding the identical names no relative. He would have been young for a supervisor in 1897. And to add to the confusion, more than one Lambeek was a member of A. et A..