The historical railway station roofs of ’s-Hertogenbosch

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Abstract

The newly constructed railway station complex of ’s-Hertogenbosch incorporates two 450m long historical station roofs, which have been restored recently. These were built at the end of the last century and constitute, as far as is known, the first steel structures to be used in a building in the Netherlands. During their lifetime, they suffered a lot of damage due to three types of problems. These problems were caused by a lack of knowledge on the loads they had to withstand, by different behaviour regarding temperature expansion than assumed in the 1890s and by technical details which made it impossible to maintain them locally.

During the restoration process, these problems have had to be taken into account and solved in order to prolong the structure’s lifetime by another century and to make maintenance possible. The aim has been to perform the restoration as discreetly as possible. Whereas the structure’s restoration is not to particularly catch anyone’s eye, an interested person should be able to see what has been done. For this reason, advantage is being taken of the fact that the object in question is an early steel structure. Corrections to the structure are being welded instead of riveted in order to demonstrate the fact that it is a steel structure and that the connection is not original.

The colour scheme, which was modified a long time ago, has been investigated. This has not only made it possible to restore the spatial appearance of this historical roof structure but also its original colours, which is very important from the perspective of architectural history. The result is astonishing. Both roofs have been restored to their original splendour, ready for the next century.
1 Introduction

’s-Hertogenbosch Station has two monumental roofs over the platforms, dating from the end of the last century. The station building itself was destroyed in the war. These roofs have been restored. Although the restoration had already been envisaged, the immediate cause of the work being started was the construction of a totally new station, a pedestrian bridge and a third roofed platform [1].

After gaining the restoration contract, Holland Railconsult first inspected the roofs thoroughly and measured and calculated them. Much historical photographic material was collected as well. The specifications and contract drawings for the roofs proved to be still in existence, but no calculations were found, however. It turned out that the roofs were not constructed entirely in accordance with the drawings and, furthermore, a number of modifications were made over the years.

This article will deal first with the problems with the roof and the resulting damage. The historical design and its subsequent alterations will then be examined and, finally, the restoration will be described.

2 The historical design and its alterations

2.1 ’s-Hertogenbosch Station

The recently-restored roofs were constructed between 1894 and 1896 to the design of civil engineer dr. ir. G.W. van Heukelom (Fig. 1). They were part of the second ’s-Hertogenbosch station building, opened in 1896 and designed by architect dr. E.G.H.H. Cuypers in a Dutch neo-Renaissance style with neo-Gothic accents (Fig. 2).

This station building, with its façade architecture, was a striking entrance to the town and took the place of a demolished town gate, the St. Janspoort, which used to stand nearby.

The roof design was an early work by Van Heukelom. The roofs are remarkable in several ways, for example their extraordinary length of more than 450 metres each. Eijmer’s southern roof of Amsterdam CS was completed only a few years before them, in 1889, and with its length of 306 metres was the longest station roof in the world at the time [2]. It was made of wrought iron, whereas Van Heukelom’s roofs were constructed of steel, or basic ingot iron, as it was then called. Analysis has shown that it was manufactured by the Siemens-Martin process [3]. As far as is known, this was the first use of steel in a building in the Netherlands. This great leap forwards demonstrated enthusiasm for the possibilities of the new material and enormous faith in his technical capabilities.
Figure 1: The construction of the roof between 1894 and 1896.

Figure 2: The station building of 1896.
Figure 3: The current situation and a view of the roofs

Figure 4: Cross sections of the roof of the second platform.
2.2 Composition of the roofs

Each roof consists of a high section flanked by lower parts (Fig. 3). The structure comprises arched latticework trusses connected by latticework purlins. The trusses are double in the high roofs and single in the low ones. The distance between trusses is seven metres in the lower roofs and more than eleven metres in the high roofs. In each section of more than eleven metres there is an intermediate truss that does not extend as far as the ground. This reduces buckling of the purlins and serves to hang the canopy from, so that the span of the canopy purlins is limited.

The cross-section of the roof over the second platform comprises 13-metre wide arched trusses with a 1.70-metre wide canopy on either side. There is glazing in the high part above the canopies and also in the top gable at the transition from the high roof to the low roof (Fig. 4).

The roof over the first platform is the same length and is of similar construction. The high part is a little wider here than that over the second platform, being 14.40 metres plus a canopy on the track side, and it connects without a canopy to the station building. The low roofs are much narrower, being 6.65 metres wide with a 1.70 metre wide canopy on one side and a 2.50 metre wide one on the other. The transition from high roof to low roof is at the same point as that from wide roof to narrow roof and results in a prominent top gable (Fig. 5).

The roof was plated with galvanised corrugated iron sheets, with two coats of white lead on each side.

![Figure 5: Cross sections of the roof of the first platform.](image-url)
2.3 Construction and subsequent alterations

The steel structure consists of riveted truss halves and lattice purlins, bolted together on site. The truss halves and purlins are fabricated from rolled angles and strips. The purlins in the canopies are of rolled I-sections.

Much of the design was altered during construction. A footbridge with stairways and ramps was constructed as a link between the first and second platforms [4]. The roof structures were locally strengthened to enable the footbridge to be supported by both roofs. This alteration was incorporated during construction.

In about 1906, a signal box projecting on both sides was added insensitively in the ridge of the roof over the second platform.

The corrugated sheet roof over the second platform was replaced by wooden roof boarding between 1927 and 1937. The galvanised corrugated sheets must have been badly damaged by the sulphuric acid content of the smoke and steam emitted by the steam locomotives. The first platform was apparently used less frequently at the time, as the corrugated panels on the high roof were retained.

Unfortunately, Eduard Cuypers’ beautiful station building was largely destroyed during fighting towards the end of the Second World War [5]. The roofs were damaged, but fortunately they could be restored. This was due in part to the high roof over the first platform, adjoining the station building, still having galvanised corrugated sheeting – probably still the original - and therefore not burning [6].

A few years later, the ruin of Eduard Cuypers’ station building was replaced in 1952 by a third station, designed by ir. S. van Ravesteyn. The railway line is still an obstacle in the town. The recently-constructed station with its footbridge is intended to improve access for pedestrians from the fast-growing western part of the town. It was designed by Holland Railconsult (architect ir. R.M.J.A. Steenhuis) [7]. The 15-metre wide footbridge cuts through the roofs in such a way that one high truss in each roof has had to be removed. The signal box and Van Heukelom’s footbridge with its characteristic ramps have lost their usefulness and have been sadly demolished.

3 Analysis of the problems and a picture of the damage

The roofs have not been without problems in the century that has passed since their construction. These problems fall into three categories. There are places where the structure is too light, so that it cannot bear the loads imposed upon it. The change in length of the roofs resulting from temperature variations was not sufficiently taken into account. Finally, the structure was built in such a way that it could not be maintained in some places and has therefore corroded badly.
3.1 Too light a structure

The structure is too lightly dimensioned here and there, probably in part because of incorrect load assumptions. The structure appears to have been designed mainly for evenly-distributed downward loads. Unevenly-distributed loads and upward wind suction had not been sufficiently taken into account, resulting in various structural members being overstressed, particularly in the ridge and – to a lesser degree – in the elbows of the roof trusses, where diagonals are missing. Finally, the lower chords of the longitudinal purlins are subject to compression due to wind suction loads. A check in accordance with the latest regulations showed that they were inadequate.

3.2 Expansion problems

Roofs that are 450 metres long expand in summer and shrink in winter up to 18cm with respect to the neutral position. Van Heukelom allowed for this by connecting the purlins with a slotted hole on one side. He built the columns in the foundations in the longitudinal direction of the roofs. The paint on the slotted holes was quickly scraped off and the separate parts became rusted or painted together, so that expansion was prevented. The columns were therefore supposed to pivot, being hinged at both the top and the bottom. Nearly all the cast iron column bases were broken as a result (Fig. 6). There should also have been a hinge in the trusses at the top of the column. The structure was stiffened here by means of cast iron ornamentation. The steel structure under this capital was regularly overstressed, while moisture could penetrate under the capital and maintenance was practically impossible. There is a great deal of corrosion damage here as well (Fig. 7). The damage deteriorates towards the ends of the roofs.

Figure 6: The column bases were broken.

Figure 7: Capital broken by pressure; the steel structure has rusted to a depth of several millimetres.
3.3 Incorrect detailing

In many places the steel structure is extremely poorly detailed from the maintenance point of view. Lack of familiarity with the corrosion characteristics of steel possibly played a part here. Steel corrodes more rapidly than iron in any case, but the details chosen would have been an unfortunate choice for iron too. The gutters were laid on the longitudinal girders in such a way that an interstice was created into which condensation was drawn by capillary action and where painting was impossible. As a result, the gutters and upper chords of the longitudinal girders are badly corroded (Fig. 8).

There is a similar situation on the walls, where the cast iron window elements were fastened to the underlying steel structure with bolts of too coarse a pitch. Rainwater was drawn by capillary action into the resulting gaps and caused serious rusting (Fig. 9), while maintenance was impossible. Pressure from the corroding steel structure subsequently broke the brittle cast window elements, rust having five times the volume of steel.

The construction of the lattice purlins is less of a disaster. The chords are fabricated from angles about 6 to 8mm apart. This construction makes maintenance practically impossible, but because of the width of the gap, condensation remains for a shorter time. The structure can dry in the wind in any case. Rust damage in these places turns out to be not so bad.

Water traps have formed in the lower chord of the trusses as a result of the construction, because another plate has been riveted on under both angles (Fig. 10). The situation here with respect to the top trusses however is most unfavourable. The water traps fill with incoming rainwater and, because the wind cannot blow through, the structure remains wet for a long time. Considerable lengths of the bottom chord members have been seriously damaged as a result. The remaining trusses are not too badly damaged, because no rainwater penetrates.

Figure 10: The lower chords of the trusses formed water traps.
4 The restoration

The purpose of the restoration is to extend the life of the roofs by fifty to a hundred years. The aforementioned problems must therefore be resolved permanently and maintenance must be made possible. It has been decided to carry out the restoration as discreetly as possible. It should not be obvious at first glance that the structure has been altered. Use has been made of the fact that it is a steel structure. In contrast with iron, steel is easy to weld. By using welded instead of riveted joints in the repairs, it is immediately obvious to the expert eye that this is not nineteenth century work. The alterations are thus directly traceable.

The intention was to make the history of the roof visible.

4.1 The structure reinforced

Strips have been welded into the ridges of the high and low trusses and into the elbows of the high trusses where the permissible stresses were exceeded, forming I-sections instead of T-sections (Fig. 11). This has brought the stresses back to acceptable proportions.

A series of tests have been set up and a numerical analysis has been performed for the bottom chords of the lattice purlins, which were inadequate according to current standards. A calculation methodology was developed [8], by means of which it could be shown that the chord members were adequate without strengthening. This has saved several million guilders on the cost of the project.

Figure 11: The structure has been reinforced where necessary by locally welding in strips.
4.2 Expansion made possible

To solve the expansion problems, the roof has been fitted with a number of dilatations, i.e. split into sections, with the result that one span is transferred to two cantilever beams (Fig. 12). It has been shown that, as far as strength and deflection are concerned, the purlins are able to take these loads; they are no longer stable however and they tip over. A solution similar to that used by Van Heukelom for the high roof has been chosen to solve this problem. The purlins are connected at the end of the cantilevers to a new stabilising system that looks like the intermediate trusses of the high roof (Fig. 13).

In order not to affect the striking transition from the high roof to the low roof, the expansion joints have not been added directly next to the high roof, but one bay further on. Dilatations have also been added to the twelfth bay of the roof ends, with the result that the longest section without dilatations is somewhat more than eighty metres long (Fig. 14).

\[\text{Figure 12: The expansion joint.} \quad \text{Figure 13: The added stabilising truss.} \]

\[\text{Figure 14: Each roof has been given four expansion joints.}\]
Figure 15: The new column bases have ball and socket joints.

Figure 16: Cast steel hinges have been welded in at the locations of the capitals.

Even with this length, damage to the roofs would occur if the trusses were not modified. The trusses are fitted with hinges to allow them to act as pivoting columns. The column bases have therefore been replaced with new spheroidal cast iron components with supports using ball and socket joints that allow movement in all directions and can also transfer negative supporting reactions (Fig. 15). These new column bases have been made slightly higher to enable removal of the serious rust damage under the old trusses and have been designed to allow the anchors to be inspected and maintained. The supports can be removed later for maintenance or replacement.

In the low roofs, an extra hinge is required at the top as well, where the cast iron capital is situated. Because of the serious corrosion damage found there, the part behind the ornamentation was cut out from the trusses and replaced with a cast steel hinge, the appearance of which resembles the capital somewhat. The designs chosen for the hinges on the first and second platforms are different because of the different designs of the trusses (Fig. 16).
Figure 17: The newly-added stability portal attaches to the girders of the old roof.

Because the high trusses are of double construction, they are, in combination with the longitudinal girders, stable in the longitudinal direction of the roofs. The low trusses, even if they have no hinges added, are unable to provide longitudinal stability because they are too flexible, so a stability portal has had to be added to each dilated part of the low roof. These portals are modern in design in their choice of rectangular hollow sections for the latticework and of tubes for the columns, but the latticework seems to belong to the longitudinal girders of the old roof when seen through half-closed eyes (Fig. 17). The portals have been constructed as lightly as possible and use the adjacent old trusses to resist longitudinal loads.

To make the history visible, it was decided to retain the old cast iron ornamentation next to these portals, along with the old grey cast iron column bases. This seemed to be possible as the expansion next to the portals played no part and distortions were therefore very limited. Further investigation revealed the quality of the cast iron column bases to be so poor that they were not fit to withstand the loads imposed upon them. This applied both to the degree to which they were cracked and to the quality of the material [9], and so they had to be replaced. It was possible however to retain the capitals at the aforementioned positions, for which the least damaged specimens from the roof were used.

4.3 Improved detailing

The gutters were in such poor condition that they had to be replaced in their entirety by hot dip galvanised steel gutters with welded-on lugs with tapped holes. These lugs were used to attach the gutters at a distance of approximately two centimetres from the underlying structure (Fig. 18). The joins could thereby be made without capillary gaps being created, so that the steel structure could dry in the wind and could be painted properly.
The steel window frames were also in such a state that they had to be completely replaced. This would normally be with welded steel frames, as was the case with the roofs at Amsterdam CS and The Hague HS stations. It turned out that it was economically possible to cast new frames for this project. Spheroidal cast iron was used instead of grey cast iron. To make it economically viable, the previous stacks of three frames were replaced by single frames, so that the number of components was reduced. To avoid having the same problems as before, lugs were cast at the attachment points on the frame units (Fig. 19). This gave no opportunity for capillary water to enter and the structure could dry in the wind. It also simplified maintenance. The lugs were drilled through on site so that the frames could be attached properly.

In order to make the old frame structure visible for future generations, one set of window frames has been retained and moved to the east wall of the second roof, where it will be the least affected by rain.

Figure 18: Gutters attached with spacer lugs.

Figure 19: Cast iron frames with cast lugs.

Figure 20: The welded top walls are also attached with spacers.
4.4 Rust damage repaired

Parts that were damaged by corrosion to such an extent that they were no longer adequate were replaced. As a steel structure was involved, it was simple to weld in new parts.

All the additions that were made in such a way look at a cursory glance like the old structure, but, because they have been welded instead of riveted, they are recognisable as being from the twentieth century. It has of course been ensured that these additions are easy to maintain. For example, two angle irons 6 to 8mm apart have been replaced by a T-section made up from two strips welded together, with similar external dimensions (Fig. 22).

4.5 Filling the gap left by the demolished signal box and footbridge

Where the former signal box stood, the roof over the second platform has been filled with new lattice purlins, with upper longitudinal girders and two intermediate trusses as support against tilting. This has restored the situation to what it was before the signal box was built. Because of the footbridge, the easternmost longitudinal girder was constructed as a web girder. It has now been reconstructed as a web girder. The purlins and longitudinal girders have been welded together from halved I-sections as chords and bracing, as a modern translation of the lattices. The overall impression is similar to the original riveted girders. The elegant column under the closed easternmost longitudinal girder, which was removed when the signal box was built, has also been restored as a modern replica. The similar column on the first platform served as a model for this (Fig. 23).
Figure 23: The previous location of the footbridge has been revealed.

The places on the walls of both roofs to which the demolished footbridge was connected have been filled with cast frames. This has restored the situation to what it was in Van Heukelom’s original design, before the footbridge was added. The canopies and scalloped edges have also been filled in.

In order to make the former presence of the footbridge visible, the closed longitudinal girders have been retained in both roofs. Moreover, it turned out that it was possible to bring the upper longitudinal girder in the roof over the first platform back to its original position after it had been partially raised at the time of electrification. This closed longitudinal girder also incorporates the start of the footbridge’s roof structure and a scalloped edge adapted for the footbridge. This makes it possible to detect the former location of the footbridge in a subtle manner without an unbalanced wall resulting (Fig. 23).

4.6 The colour

The steel roof structure in ’s-Hertogenbosch was finished in shades of grey during recent decades; the roof boarding was naturally oiled. The expert knowledge of the Rijksbouwmeester bureau was called upon after doubts had arisen over the originality of this colour scheme. Testing paint samples from the roof structure and studying historical photographs of the roofs yielded the following surprising result [10] (Fig. 24).
All the coats of paint applied since construction were shown to be still there: 18 or 19 layers with a total thickness of more than 1.5mm! This meant repainting once every six or seven years if undercoats are ignored. This good maintenance and great thickness of paint explain the exceptionally good condition of the structure, relatively speaking.

Based on the degree of contamination of the transition between the colour layers, it could be checked what the colour of a topcoat was. The structure had been undercoated with red lead, painted over with yellow-green, transported to the site and erected. The finished structure was given a topcoat of a blue-green colour. This approximately 0.25 mm thick topcoat was the roof structure’s colour for a long time. The decorative edging – and probably the gutters as well – were then painted over in a yellow ochre colour. As has been stated earlier, the corrugated sheets were painted with white lead.

Years later, the entire roof was painted over several times on several occasions in shades of yellow, finally undergoing a change of colour in the years just before or during the Second World War to the shades of grey we were familiar with.

It was decided to restore the roof to its original colour. The entire structure, including the window frame components, was therefore given the blue-green colour. Only the decorative edging and the gutters were painted in yellow ochre. The boarding became creamy white, with sufficient reflection of light in view. As a result, the original design of this important roof has been reconstructed not only in its spatial appearance but also in its authentic colours, which is important from the perspective of architectural history. The result is surprisingly beautiful.

Figure 24: Painters at work in 1896.
4.7 The method of execution

The initial basic assumption was that the roofs would be restored in situ, but there was a change of direction at the specification stage. Because of the nuisance to railway traffic, passengers and those living in the immediate vicinity and considering the extensive alterations that were necessary, it was decided to remove the roofs. This meant the work was less susceptible to being affected by the weather and it was possible to guarantee a more consistent quality of work. Moreover, it could be carried out more cheaply.

Because of the way the roof was built, it was simple to dismantle it by undoing the original bolted joints. The roof components were stored in the middle of the platforms so that they could be transported by train to a location where they were transferred to trucks. The roof components were subsequently blasted clean. Holland Railconsult assessed which modifications were required. The components were modified as required and once more preserved in their original 1896 colours. They were then returned to the site. In this way both roofs were transported from the south to the north in pieces, smartened up and re-installed, after which 28-mm thick wooden boarding, painted cream, was bent over the purlins and attached to them. Finally, an artificial rubber roof skin was applied.

5 Conclusion

The historic roofs in 's-Hertogenbosch have been thoroughly restored. This article describes – after a look back at the history – the problems with the roofs and their restoration. Problems present were solved in a permanent manner and maintenance was made possible. The aim was to carry out the restoration as discreetly as possible. It does not appear at first glance that the structure has been altered, but the modifications are clearly visible to the interested observer. The history of the roof is also visible.

Both roofs were restored to their full glory in early 1999, ready for the next century.

References

728  Structural Studies, Repairs and Maintenance of Historical Buildings

[NS Technical Investigation, Investigation into the material of the roof of 's-Hertogenbosch Station, November 1994 and January 1995 (not publicly available).]


[C. Douma, The Station Building: History, location, layout and design, new developments, published by NV Nederlandse Spoorwegen Information Department, September 1974.]


[NS Technical Investigation, Analysis of cast iron column base in Den Bosch, March 1997 (not publicly available).]

[E.J. Nusselder, Expert advice on the colour of platform roofing at 's-Hertogenbosch, State Building Department, November 1996 (not publicly available).]