Tjalling de Vries, Public Works Department, Rotterdam:

‘Complex calculations for the roof of the new public transport terminal’

The engineering firm of the Rotterdam Public Works department (IGWR) is one of the biggest of its kind in the Netherlands, with hundreds of specialists calculating the feasibility and safety of harbours, bridges, tunnels and buildings. But, as IGWR’s Tjalling de Vries admits, the design for the roof spanning Rotterdam’s new public transport terminal hall was so unusual that ProRail and the Municipality of Rotterdam called on TNO to investigate the effect of the wind load and wind hindrance on travellers.

Photo: Ben Wind

‘The roof of the terminal was designed by a group of architects called Team CS. It was formed from the agencies Benthem Crouwel, Meyer and Van Schooten along with West 8 Urban design & landscape architecture, all of whom have well-known designs to their name. The terminal consists of two interconnected parts: the northern section – the platform roof – and the southern entrance hall. Not only is the design of the southern hall remarkable but so is the entire project of the public transport terminal. Many parties are involved. ProRail and the Municipality of Rotterdam are responsible for the entire infrastructure. ProRail itself has an engineering firm and contractor for the design of the roof spanning the railway tracks. Since the Municipality of Rotterdam is co-owner of the passenger terminal, IGWR was itself responsible for calculating this structure. The two structures quite literally interface. The substructures move individually, they translate forces to the each other. And that requires very careful adjustments.’

COMPLEX STRUCTURE

‘Traditionally, there is a certain tension between architect and structural engineer. In short: the architect wants to create something special and the engineer subjects this to calculations. Beauty is an important issue but also the safety requirements must be met. We already had discussions about the first design with the architect. The ratio between the height of the structure and the length of the span was a big challenge. We finally agreed: the original design with the folded roof could entirely remain intact,

‘The result is a wonderfully shaped but very complex structure of steel and glass measuring roughly 160 by 80 metres and containing a lot of variations in height, knuckles and folds. A very special design that really captures the imagination. But what actually happens in practice? What do the travellers notice if it’s blowing a gale? How does the wind affect the structure? Very strong winds can cause the roof to move by several centimetres, just like the swaying motion at the top of the Eiffel Tower, without however anyone noticing anything. So that is not a problem as long as the structure can bear the movements. The pressure and suction by the wind is difficult to predict for such a complex design like this. A wind tunnel is needed to measure this.

‘There are a few wind tunnel options available in the Netherlands, but for us TNO was the right choice. Different municipal departments have had good experience of TNO and apart from doing the rests in its wind tunnel, TNO provided much more in terms of expertise. Its multidisciplinary approach is of significant value to us.’

VIBRATIONS

‘In the wind tunnel TNO experts simulated wind gusts in order to determine the extreme loads on the structure; they performed measurements to identify the possible hindrance of the wind from outside for the travellers and they also undertook smoke tests in the event of fire. The results of the research on the wind gusts were used by us in the calculation model, and this was incorporated in the design. Subsequently, we were then able to take the necessary measures and we introduced a few minor modifications to the structure.

‘The wind tunnel research generated surprising results. The wind velocity pressure was much larger in some locations than prescribed by the building code. Therefore we are happy that TNO carried out these measurements. Furthermore, the calculations by structural engineers of IGWR revealed that the hall’s natural frequency was in the risk zone of the wind load spectrum. Calculating vibrations is extraordinarily complex, and everyone knows the story of the stay cables of the Erasmus Bridge that, shortly after being opened, appeared to sway at certain wind speeds. Good reason for TNO to investigate the effects of the wind vibrations on the roof. This led to a few more minor modifications that, in turn, had an impact on the rest of the structure. So therefore we had to perform new calculations once again.

‘Finally, on our request TNO once again looked critically at all the calculations, and this *second opinion* provided us the hundred per cent security that everything in the engineering had been done correctly. Of course, it’s great to know that we have done our job well but more important is the reassurance that the travellers and people working in and around the public transport terminal run neither risks nor experience any hindrance.’

The TNO expertise

Dr Raphaël Steenbergen, MSc and Carine van Bentum, MSc, experts in structural safety.

‘The engineers of the Rotterdam Public Works department have a good reputation both at home and abroad. They have all the necessary expertise in house to calculate the roof span of the public transport terminal hall. But in this case a whole range of engineering issues conjoined: the safety of the steel structure itself, wind load, smoke formation. So our expertise was not limited just to structural safety. We gathered together specialists from various disciplines to assess everything in a coherent way. How does the wind affect the roof span in extreme conditions? What do people outside notice? How does smoke displace in the event of fire? How does the glass and steel structure respond in extreme situations? All very different areas of expertise that on their own can provide answers to very difficult questions but which, if considered together, can really add value. The key word is here: structural safety. That is the basis of all our research, tests and calculations.’

The customer

The engineering firm of the Rotterdam Public Works department (IGWR) is active in the field of infrastructure, buildings and environment. The Rotterdam Public Works department has a nice saying for this: ‘shaping Rotterdam and keeping Rotterdam in shape’. Around a thousand people are employed at IGWR. Their fields range from civil engineering, landscape architecture, environmental sciences and geography to social sciences and communication. Given its considerable knowledge and experience, it is not only engineering firms at home that call on the services of IGWR but its engineers are also called in all kinds of major projects abroad.

Tjalling de Vries, MSc is chief steel engineer at the engineering firm of the Rotterdam Public Works department.