Peperkoekbeton en Pisbakkenstaal

Freely translated from Dutch as: gingerbread concrete and urinal steel.

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In accordance with the Eurocode, most of the new building structures are designed based on a reference period of 50 years. In contrast, approximately 40% of the current building stock in the Netherlands is composed of buildings that are quite a lot older. Most of these buildings have a structure standing proudly upright and functioning, such as the one presented in *Figure 1*, sometimes surprisingly well, even though the design reference period has long passed, and the building regulations used at that time to design the structure are no longer valid.

Of course, the existing structure does not know that we have new building regulations. Therefore, the structural engineers working with existing buildings have a leading role in the design process by thoroughly understanding the existing structure in terms of material and mechanics, especially in the historical context.

Figure 1: Timmerfabriek in Vlissingen

Developments in structural engineering

The structural typology of the existing old buildings in the Netherlands generally evolved from using timber and masonry to combining steel and concrete, and later to reinforced concrete. The material quality is often lower than what we are accustomed to in the design of new structures, as the production technology hadn't developed as much. Jokingly, materials are referred to as 'gingerbread concrete' (approximately C12/15) and 'urinal steel', even though the intended steel quality is quite comparable to S235 used today.

Although some standardized products, such as steel normal profiles NP (now known as INP) and wide flange beams DIL/DIN (comparable to HEA/HEB), were available on the market, standardized building regulations did not exist at the beginning of the 20th century. The available knowledge was documented in books by several specialists. These predecessors of the current building regulations were not as comprehensive as today's standards. They were primarily intended to achieve some control over the average qualities of the material, or they prescribed design loads or structural or architectural detailing for different types of structures.

Next to these developments, the building culture regarding comfort was different as well. For instance, apart from the use of cavity walls in some buildings, thermal insulation was often not considered at all, and a lower level of comfort was more commonly accepted as something that everybody had to contend with. Also, labor was relatively inexpensive, whereas building materials were relatively costly. Due to that, structures were often economically engineered with thin concrete floors or lightweight timber floors and roof structures. Columns, on the other hand, usually had a large overcapacity due to a safety approach, different from what we use today.

Repurposing

When assessing an existing structure for repurposing, it is important to consider it within its own historical context. What was the structure's original purpose? How was it used over the years? What was the quality of the used materials, and what changes or repairs have been made in the past and can existing damage be related to that? In addition to archival research, the structure is inspected on sight, if possible, to review its current state and to get a feel for the material characteristics. An example of existing damage due to fire is shown in *Figure 2*.

Figure 2: Damage due to fire in Kantinegebouw Enka, Ede (left), Deformed timber structure in Steenfabriek, Elden (right)

Unwanted issues, such as deflections, as presented in *Figure 3*, or vibrations of floors, or limited sound insulation of separation walls, may be characteristics that need to be dealt with. It is often unrealistic to expect that all the rules for new buildings, according to the Dutch Besluit Bouwwerken Leefomgeving (former Dutch Bouwbesluit 2012), can be met, especially concerning existing structures. A better approach is to begin at the minimum requirements for existing buildings and strive to meet a higher standard where this is structurally feasible and economically viable.

Therefore, the design standards for existing buildings and renovation (Dutch: bestaand/verbouw) should be the starting point for determining the possibilities regarding the existing structures. Depending on the type of building (industrial, storage, living) the structure can offer more or less possibilities. The main goal is to advise on basic principles instead of very detailed engineering. Nevertheless, some parts of the structure should be assessed in more detail, as these can be governing for the permissible loads on the structure. For example, steel details can be measured, but the concrete reinforcement for the total building may often not be known.

Once a thorough understanding of the structure and its potential flaws is established, the strategy is to use all this knowledge as a strength to contribute to the design rather than regarding it as a limitation. Unlike shaping the building to a function, as is common with new buildings, the goal is to guide and advise in fitting a function in an existing building as well as possible, whereby a certain degree of reticence is maintained regarding changes in the existing structure. This way, the proven structural scheme remains intact, and the chance of new damage is limited.

Practice

In general, a project starts with a visit to the building to get a first impression of its condition. Depending on the quality of the structure, deflections, missing parts, and other factors, advice for repurposing can be given (or not). In repurposing the design, additional or more detailed inspections can be conducted. If necessary, destructive research to determine the actual material properties can be part of the scope in the design phase. Collaboration with the other team members is always an interactive process throughout the design.

Using digital scanning techniques, a point cloud model of the building can be generated, and a structural model can be derived from that. With this model, which shows the actual dimensions, deflections, and tilting, a better understanding of the structure can be obtained. This is important because, as opposed to a traditional new building design process, detailed calculations of governing parts of the existing structure are required in the early design phase to be able to give proper advice to architects and developers.

Role of the structural engineer

The structural engineer will be subjected to many challenges: prove the functioning over time and ensure the safety for a future purpose of the existing structure. In the design process, a comprehensive understanding of existing buildings is essential. Important aspects are their material properties, building methods, foundation characteristics, restoration methods, (see *Figure 4)*, and more is essential to be able to provide complete advice. In addition, the state of the art of structural design should also be part of the structural engineer's toolkit since new elements will be implemented in existing structure. This makes the 'repurposing structural engineer' act in the two worlds of structural engineering. ◄

Figure 4: Restoration in the Central Markthal, Amsterdam