Conservación, reutilización y ampliación de estructuras de edificación: una perspectiva suiza

Preservation, reuse, and expansion of building structures: a Swiss perspective

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RESUMEN

Suiza se ha fijado el objetivo de alcanzar la neutralidad climática en 2050 y reducir a cero las emisiones de gases de efecto invernadero. Dado que alrededor del 38% de las emisiones de CO_2 proceden del sector de la construcción, una planificación estructural prudente y dedicada puede contribuir significativamente a reducir la huella de CO_2 en el futuro. Este artículo presenta diferentes proyectos de estructuras de edificios desarrollados por nuestro estudio, en los que se han aplicado diversas estrategias novedosas para garantizar su conservación. Además, se presentan ejemplos de los primeros proyectos piloto que persiguen la economía circular en la construcción.

ABSTRACT

Switzerland has set itself the goal of becoming climate-neutral by 2050 and reducing greenhouse gas emissions to zero. Since around 38% of CO_2 emissions worldwide are caused by the construction sector, cautious and dedicated structural planning can make a significant contribution to reducing the CO_2 footprint in the future. This paper presents different existing building structures projects developed by our practice, in which various novel strategies have been implemented to ensure its preservation. In addition, examples of first pilot projects pursuing circular economy in construction or reuse of dismantled structural elements from existing buildings are introduced.

PALABRAS CLAVE: conservación, reutilización, circularidad, Suiza
KEYWORDS: preservation, reuse, circularity, Switzerland

1. The Swiss normative framework for existing structures, the SIA 269

Even though methodologies inherent to existing structures exist for over 40 years, there are still not commonly applied in practice, due to the lack of normative framework.

For this reason, the Swiss Society of Engineers and Architects published in 2011 the SIA 269 [1], which defines the normative framework in Switzerland for existing structures. This standard specifies the principles and the appropriate methodology for dealing with existing structures. This standard is complemented by a series of standards which treat specific items regarding 'actions on existing structures', 'existing concrete, steel, composite, timber, and masonry structures', 'geotechnical aspects' as well as "seismic aspects of existing structures".

The set-up of the series of SIA 269 standards is thus analogous to the European standards for the design of new structures. Issues referring to both existing and new structures remain in the standards for new construction, that is, the standards on existing structures are complementary to the standards for the design of new structures.

Since its publication, almost 15 years ago, the SIA 269 has been widely accepted and applied not only by the Swiss structural engineering community, but also by developers, and other stakeholders, resulting in a valuable tool for the cost-effective evaluation of existing structures. These standards present an important opportunity for the training of the structural engineering community in the domain of existing structures, allowing to exploit its potential and ensuring its preservation, as well as reducing the overall CO_2 emissions of the sector.

2. Felix Platter Hospital, Basel, Switzerland

2.1 Existing structural system

The former Felix Platter Hospital in Basel is a listed building, which was constructed during the years 1962-1967. It has been recently converted into a community-oriented residential building with 130 flats. The project aimed to preserve the structure of the existing 100x20x35 m reinforced concrete building. Fortunately, most of the execution engineering plans were available, which notably reduced the engineering effort for updating the information and allowed an optimized planning of the intervention measures. The proposed key interventions were the incorporation of a double height foyer, a distribution corridor with cascade-like stairs and new cores with lifts and staircases. The main structural system remains unchanged. To avoid further intervention measures, the permanent and live loads remained limited to their original values. This project is a clear example for the conservation of resources and follows the famous Swiss principle "conversion instead of demolition".

2.2 Seismic retrofitting

As part of the rehabilitation project, a seismic retrofitting with additional shear walls was carried out to increase the lateral stability of the building and fulfill the current safety requirements (Figure 1). These supplementary retrofitting elements were clamped to the ground using micropiles. Furthermore, the three expansion joints of the building were monolithically closed to ensure a convenient dynamic behavior of the whole deck slabs as a continuous membrane.

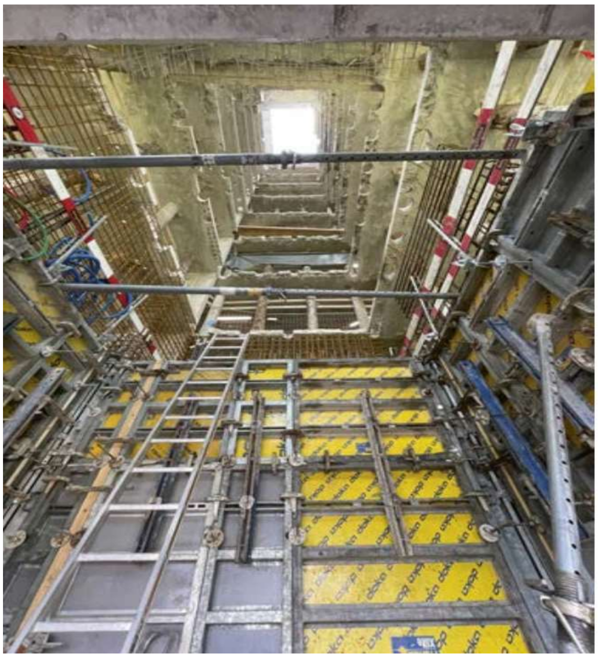


Figure 1. New construction staircase

2.3 Conversion concept for foyer

For the execution of the entrance hall within the existing building, a complex construction procedure with temporary active propping founded through micropiles was developed. Once the existing structure was secured, the demolition works were performed and the definitive supporting structure featuring new transfer walls on the first floor and two-storey high exposed concrete columns was executed.

In order to avoid retrofitting measures at the existing foundations, the punctual loads coming from these new columns are evenly distributed in the ground thanks to the introduction of additional transfer walls in the basement level. (Figure 2)

Figure 2 Conversion concept for foyer: existing building, temporary propping/demolition and new construction.

3. Rehabilitation of the “Haus Du Pont”, Zurich, Switzerland

3.1 Existing structural system

The historic Du Pont office building is a double-wing nine-storey building in the centre of Zurich. Originally constructed in 1913, the building has recently been converted into a hotel. The structural system, which is highly effective and was very innovative at the time of its construction, represents one of the best examples of early reinforced concrete structures.

The structural system consists of reinforced concrete rib slabs supported by floor beams and columns. The original building boasted a cinema auditorium on the ground and first floors which did not have any columns. The four upper storeys were suspended from the reinforced concrete structure in the attic by hanging columns, which transferred the loads to the façade columns.

3.2 Rehabilitation of the ribbed floor slabs

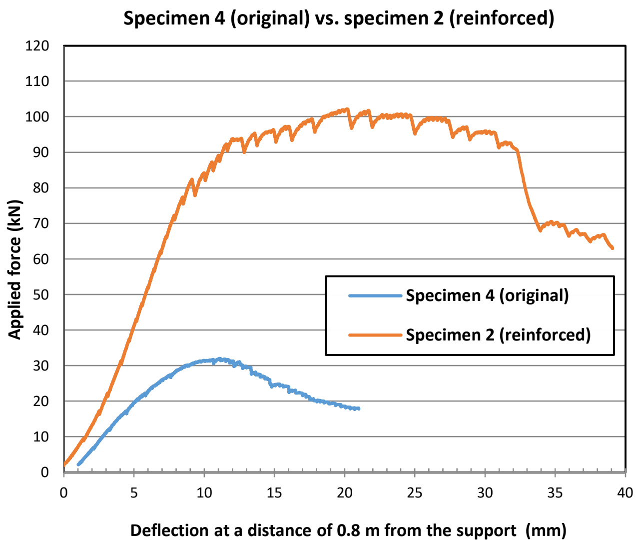
The ribbed floor slabs act as multi-span beams bridging 6.5 m. The reinforced concrete ribs are 24 cm high and 9 cm wide. They are connected by a thin, 6 cm thick connection plate, and each rib contains only two smooth longitudinal reinforcing bars. An initial structural assessment revealed insufficient capacity at the intermediate supports, where the maximum combined shear and bending moments occur.

Due to the large number of ribs to be strengthened, an ultra-high-performance fibre-reinforced cementitious composite (UHPFRC) [2][3] overlay was applied. The monolithic bond between the existing concrete and the UHPFRC layer was achieved due to the surface roughness. A 40 mm layer of reinforced UHPFRC resulted in an increase in the bending–shear resistance sufficient to satisfy the new requirements.

Due to the importance of the building, it was decided to carry out experimental investigations. Three-point bending tests were executed which illustrated the critical bending–shear interaction in the region of the intermediate supports (Figure 4).

The test results confirmed the suitability of the chosen strengthening approach. A summary of the test results can be seen in the two diagrams shown in Figure 3. In the right-hand diagram, the test results are compared with the model estimates, and good correlation can be observed. The left-hand diagram illustrates the comparison of the load–deformation curves of a UHPFRC-reinforced and an unreinforced specimen. The effect of the UHPFRC layer is clearly discernible from the significant increase in the bearing capacity, the ductility and the stiffness of the specimen.

The application of the UHPFRC layer was challenging. A total of 120 m^3 of UHPFRC was prepared on site, and 4,500 m^2 of the existing concrete surface was roughened. The thixotropic UHPFRC was applied manually with a vibrating beam screed to ensure sufficient compaction of the UHPFRC and effective bonding to the existing concrete (Figure 4).



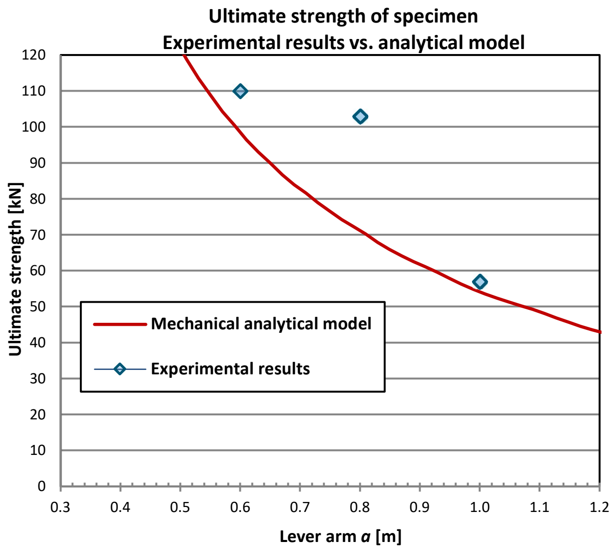


Figure 3 Left: force–deflection curves of a UHPFRC-strengthened and an unstrengthen test specimen; right: comparison of the experimental results and the estimates obtained from mechanical models.

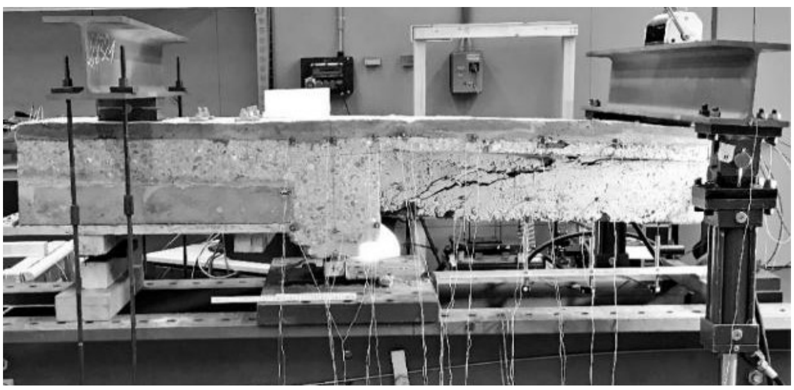


Figure 4 Left: application of UHPFRC layer; right: test specimens and test setup.

3.3 Modification of the structural system

The structural system of the existing cinema hall was modified (Figure 5). Originally, four storeys were suspended from the roof by hanging columns, and the floor above the cinema auditorium was supported on three floor beams spanning 16 m between the facades. To minimise any intervention on the suspension structure, the hanging columns were cut (Figure 5), which resulted in the reduction of the number of storeys (two instead of four), the lightening of the load on the roof structure and the preservation of the original structural system of the roof. The other storeys were supported on new columns which transfer the load directly to the new foundation. To preserve the hanging columns, the spacing of the new columns was kept identical to that in the original building. The new interior columns allowed the floor beams above the cinema auditorium to be replaced by lower beams and two new storeys to be created (Figure 6)

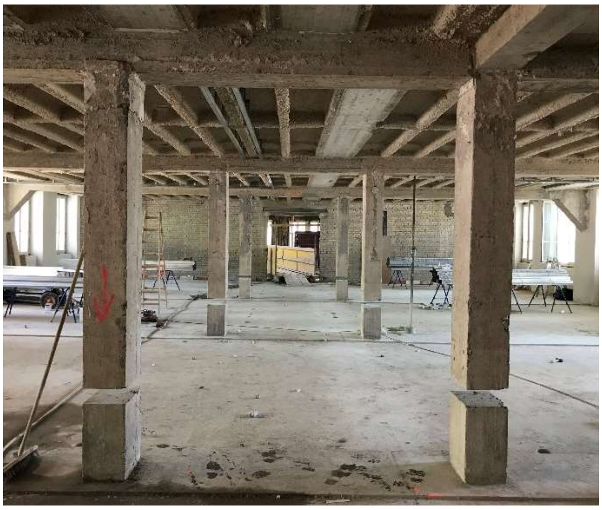


Figure 5: Columns cut during the construction.

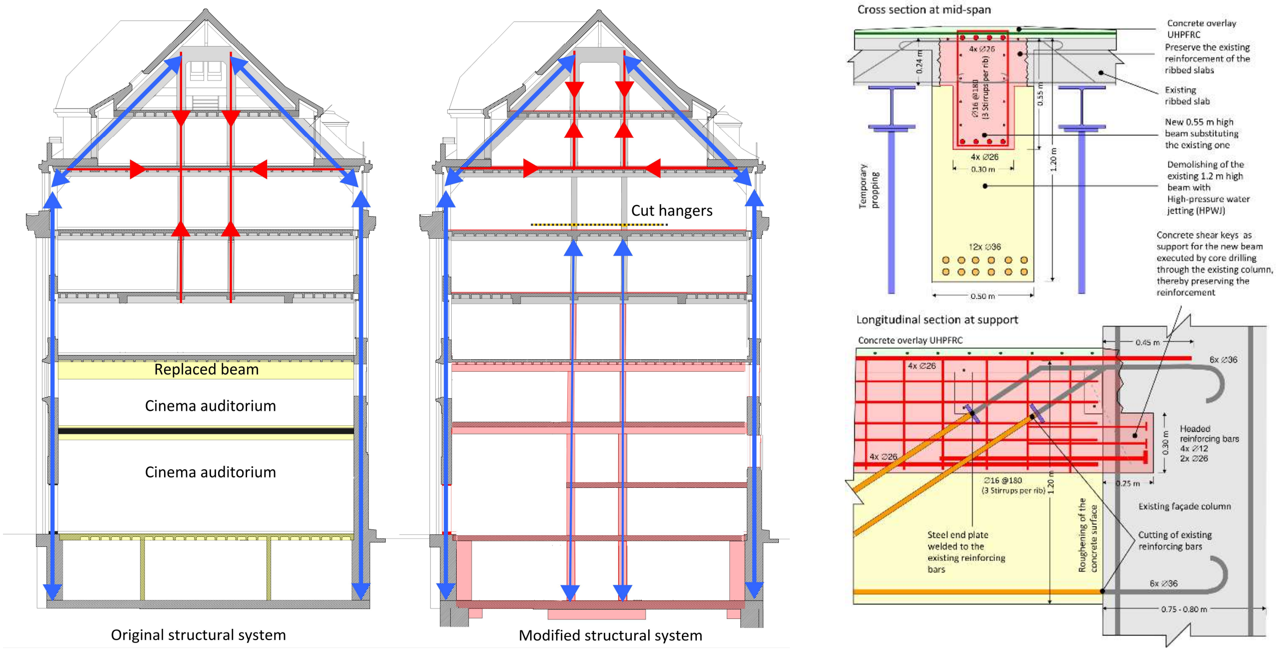


Figure 6 Left: original structural system; centre: modified system; right: replacement of the floor beams.

4. Underground water reservoir, Zurich, Switzerland

In 2022, our practice was commissioned to investigate the preservation of an underground drinking water reservoir in the city center of Zurich dating back to 1871. The reservoir is out of order since 1970 and the rehabilitation project observes its partial demolition due to the extension of the existing tram lines of the street nearby and transform it in a restaurant or event venue with an external garden area.

4.1 Supporting structure, adaptations, and measures.

The reservoir consists of three different parts (Figure 7), which were built during different time periods. The two older parts from 1871 and 1886 (Reservoir 1 and 2) are built using arched supporting structures made of masonry and concrete. The arched vaults transfer the loads in a direction transverse to the dividing walls, from where the forces are transferred to the ground. The outer walls are designed as arched retaining walls and gravity retaining walls. When the reservoir was still in use, the earth pressure balanced the water pressure. The entire structure acts like a pressure vessel. The Reservoir 3 was rebuilt in reinforced concrete in 1937. According to the soundings, the reservoir is covered with a thickness of approx. 1.3 m of soil from the top of the ridge.

To provide the space required for the new uses, part of the roof vault, the outer walls and the dividing walls inside the reservoir will be demolished. This will change the entire structural system and therefore various countermeasures are required to ensure stability.

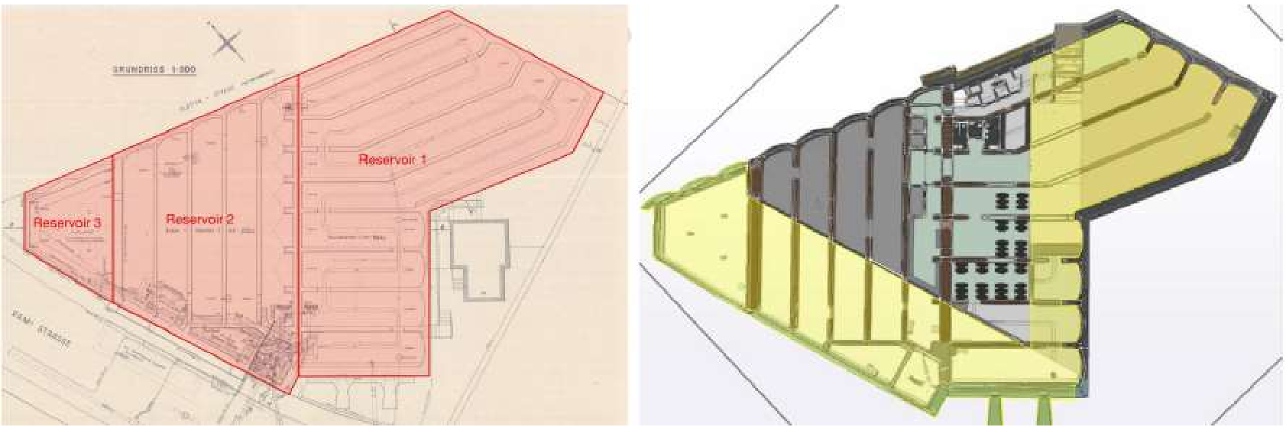


Figure 7 Left: existing structure with the different parts; right: in yellow, partial demolition of the reservoir

4.2 Stability measures for the existing outer walls.

One of the most critical components are the partially demolished masonry outer walls around Reservoir 1, where the roof vault will be also demolished. Depending on the remaining length of the wall and the backfill height, a different hazard scenario may occur. The horizontal force transfer is critical. In the current state, this takes place via a counteracting compressive force and friction with the floor slab. The compressive force is removed by shortening the walls and the removed roof vault also eliminates the vertical force required for friction. Tilting and sliding safety of the wall cannot be fulfilled as a result.
As a direct measure against sliding, the remaining benches can be used at the end of a partition wall. To maintain the required vertical load and corresponding friction for the stability of the walls, an external loading will be applied by means of prestressed stainless-steel bars.

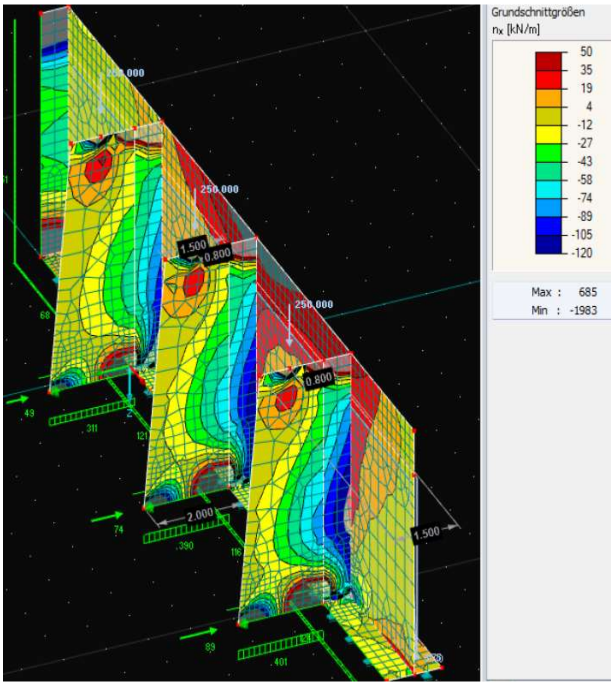


Figure 8: Static analysis of the modified outer walls

The prestressing force is applied to the masonry by means of a steel plate. Micropiles are used to anchor the prestressing force in the ground (Figure 9). This ensures the force transmission of the anchoring into the ground.

Figure 9 Visualization of the finished project

5. WIFAG urban development, Bern, Switzerland

The traditional approach of demolishing existing buildings when constructing new replacements is associated with high environmental costs. It causes excessive CO_2 emissions, consumes enormous amounts of energy and materials, disturbs the population through noise and vibrations and often ignores the potential for recycling and reusing valuable building materials. The WIFAG site in Bern is a former industrial area comprising various existing buildings and halls, which are planned to be partially demolished and replaced by a new residential development (Figure 10).

For ecological reasons, the existing basement construction is to be preserved and whole new buildings will be placed on top, following to several structural challenges. Preserving the underground levels means that up to 10,000 tons of CO_2 can be spared in comparison to rebuilding it, which is equivalent to the emissions of 10'000 cars per year.

The existing basement was built in four different construction phases (1964 to 1992) as a robust reinforced concrete construction planned to sustain live loads up to 3 tons per square meter. The structural system of the basement comprises a skeleton structure featuring flat slabs with localized reinforcements in the column areas spanning up to 12.50 meters offering a great flexibility of use and is grounded on shallow foundations. The building is in good condition and is suitable for slight conversions and/or changes to the structure, such as the creation of openings in the slabs or closing recesses.

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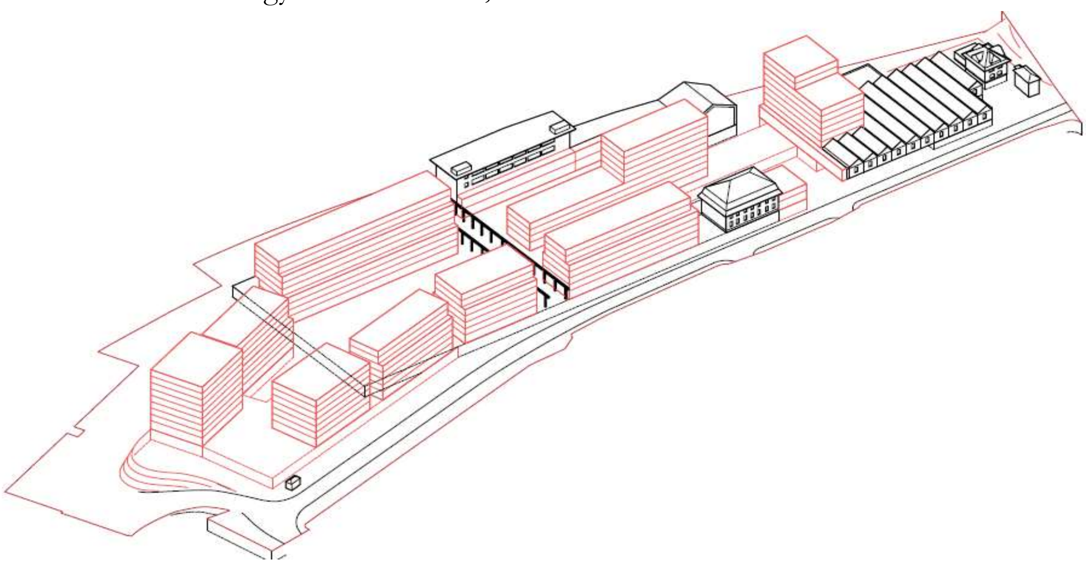

Figure 10 Overview of the master plan for the WIFAG site, with the new constructions displayed in red.

The new buildings are designed to be as light and sustainable as possible using timber as the main structural material. The vertical load transfer of the new buildings in the existing basement is guaranteed via additional columns or walls. Adopting the existing basement grid for the new buildings is pursued and conceivable in most cases, requiring appropriate reinforcement measures in the existing columns and foundations. When the direct transmission of vertical loads is not possible, transfer elements are planned.

The horizontal stabilization of the new buildings against seismic loads and wind is guaranteed by introducing continuous reinforced concrete cores or shear walls running through the existing basement and anchoring them in the ground. The existing concrete cores are not suitable for stabilising the new buildings due to their different layout, height and safety requirements and therefore corresponding larger seismic loads.

If the load level is similar to that of the existing buildings, the force transmission of the new buildings into the subsoil can be directly absorbed by the existing foundation. If the load distribution deviates greatly from the existing structure or if significant new concentrated individual loads, further measures must be taken (e.g. micropiles) drilled through the existing floor slab.

The WIFAG site project also pursues the goal of circular construction by reusing dismantled structures from existing buildings wherever possible. In particular, the numerous steel structures to be dismantled are predestined for reuse. This means that the steel profiles can be used in new buildings. For example, they can be used to create the balcony structures, the supporting structure of attic storeys or pavilions for landscaping. Dismantled concrete structures, on the other hand, are to be recycled and reused in the form of recycled concrete or can be used as panels for the façade or the landscaping.

6. Circularity: first applications in our practice

Currently, selective dismantling and deconstructable construction as components of the circular economy are still insufficiently applied in practice in Switzerland. However, increasingly discussions and studies have been published in recent years, which aim to address some of the main barriers to their implementation. These obstacles include, for example, the lack of exchange between experts, the lack of sharing of best practices, but also the insufficient overview of options.

Despite the complex legal, administrative and organisational framework associated with the circular economy in the construction industry, our practice is developing different façade projects in which the reuse of building elements has been successfully applied. The reuse of structural elements has also been proposed for the construction of moderately complex and challenging structures.

6.1 Remanufacturing the Spandrel Glass Panels of the Herostrasse Building, Zurich

The Herostrasse 5 Building in Zurich from 1973 showcases a significant application of circularity, where the glass was directly mined onsite. The façade consisted of floor to ceiling height elements in timber, steel, and glass.

In 2021, the city of Zürich decided to refurbish the façades without taking the building out of service. To meet the compulsory energy and acoustic targets, the insulation layers and the windows should be replaced with state of the art components. As a key part of the proposal, the characteristic red enameled glass cladding was proposed to be conserved.

As expected, 50-year-old building parts were not meeting today's requirements, including the glass cladding. For glass cladding, a safe failure mode and post failure resistance are demanded. Therefore, a new glass cladding would have required laminated safety glass.

Early dismantling allowed investigation of the technical buildups and time to analyze the glasses. The optical stress assessment, carried out by the Competence Centre Facade Engineering of the Lucerne University, evidenced a pre-stress in the glass. The variation of the stress readings indicated that the glass had been thermally prestressed. The level of the prestress lies between a heat strengthened and a fully toughened glass.

After the technical and visual assessment, it became clear that the glass could be reused visually without any negative effects. A life span of another 40 to 50 years was deemed to be possible. Nevertheless, the technical investigation showed that the glass was lacking the required impact performance consistent with safe failure mode and a post failure resistance. A reuse by simple cleaning and reapplication was therefore not possible. A remanufacturing process was required to meet state-of-the-art performances and alternative solutions were investigated. Laminar bonding based on silicone was then identified as a possible enabler technology and material. Besides the technical benefits for application and services, the possible and simple material separation at the end-of-life span were key factors for choosing the solution.

For the project, silicone was used to bond a perforated back sheet in aluminum to the glass. The composite buildup of the architectural inspired enameled glass, silicone and the perforated back sheet ensures the required performance such as invisible fixation, unchanged glass color and glass haptic, safe failure mode and post failure resistance (Figure 11).

The application trials proofed that remanufacturing works efficiently and is safe. For the Herostrasse project, remanufacturing is ready for the execution. Therefore, the glass cladding will be dismantled and, as soon as the glass pieces are stored in cradles, the aspired industrial-based remanufacturing process can start. Once glass is cleaned, laminar bonding will be applied, and the back sheet will be embedded into the silicone. Silicone can be dispensed in several ways adapted to the selected back sheet, to ensure full coverage. Finally, the glass pieces can be delivered back on site.

Figure 11 Application of the silicon layer on the existing spandrel glass panels.

Conclusions

In the author's experience, the decision to reuse existing structures rather than build a new one is driven by factors such as cost-effectiveness, sustainability, technical factors, regulatory incentives, and time constraints. Owners and promoters are often motivated by the potential savings in materials and labor, the reduced environmental impact, and the possibility of preserving historical or architectural value. The technical challenges of evaluating an existing structure play also a crucial role in determining whether a reuse solution is feasible. Owners and promoters are more likely to opt for reuse when the cost of structural adaptation is lower than demolition and new construction. Additionally, sustainability initiatives and regulatory policies promoting carbon footprint reduction play a significant role in encouraging the rehabilitation of structures rather than their replacement. Historical or architectural value, zoning restrictions, and social considerations can also influence the decision to retain an existing structure.

One of the key aspects of structural reuse is the necessity for a clear and systematic evaluation methodology. Unlike new builds, where safety levels can be objectively determined based on well-defined standards, the safety of an existing structure is highly dependent on the accuracy of condition surveys, data acquisition, and expert judgment. Standards, while useful, do not provide a straightforward answer, and engineers must rely on their experience and knowledge to make informed decisions. The subjectivity of safety assessments in existing structures—where confidence in the structure's reliability evolves with additional information—further complicates decision-making.

In contrast, new constructions offer a more predictable level of safety, as design parameters are clearly defined by standards. This objectivity often makes new builds more appealing when uncertainties in existing structures cannot be resolved efficiently.

The challenge in promoting reuse lies in bridging these uncertainties with rigorous evaluation, ensuring that rehabilitated structures meet modern safety expectations while maintaining proportionality in assessment and intervention.

Ultimately, the choice between reuse and new construction is not merely a technical decision but a balance of economic feasibility, safety perception, and long-term sustainability goals. A structured approach to evaluation, supported by thorough condition surveys and expert judgment, is crucial in making a reuse solution viable and attractive to stakeholders.

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