

APPLICATION OF STEEL BAR BRACINGS IN RENOVATION AND MODERNIZATION OF HISTORIC BUILDINGS

Krzysztof KUCHTA¹

Cracow University of Technology
Faculty of Civil Engineering, Kraków, Poland

Abstract

The use of steel bracings is possible in all four stages of engineering activities in the renovation and modernization of historic buildings, i. e.: protecting, repairing, strengthening and rebuilding. Steel bracings are auxiliary structural systems, which, due to their relatively small cross-section dimensions and low weight, provide an efficient way to achieve the required resistance and stability of the original historic building structural systems. The steel structure in most cases is the tissue that differs in style and material of genuine tissue which is present in a renewed historic building, but is also often a rational solution acceptable to the conservation and structural point of view.

Keywords: steel bracings, historic buildings, façade retention, renovation, refurbishment, strengthening, reconstruction, temporary support systems.

1. INTRODUCTION

Maintaining in the best technical condition architectural monuments, including the original support structure, it is not always quite possible, especially when the object is subjected to partial reconstruction, strengthening or adapting to new user requirements. In such cases, the scale of construction intervention should not exceed the limit of the necessary actions, and its scope should be defined by curator's decision. In terms of architecture and design restoration of

¹ Corresponding author: Cracow University of Technology, Institute of Building Materials and Structures, Chair of Metal Structures, Warszawska st 24, 31-155 Kraków, Poland, e-mail: kkuchta@pk.edu.pl, tel.+48126282372

historic building should be done in a style consistent with the time of its creation, and made of materials similar to the real, existing in renewed property. The number of architectural monuments of the supporting structure made of steel in our country is relatively small, but the structural steel sections can be successfully used also in buildings of masonry or timber structure. In many cases, above mentioned conception has no alternative, at the same time - providing a rational solution acceptable from the conservation and structural point of view.

In the context of renovation and modernization applications, the advantages of modern structural steel include:

- high ratio of strength to their own mass, so that superstructures and reconstructions are less heavy on the historic walls and foundations,
- the relatively small depth of structural sections, which is extremely useful for dimensional limitations "inherited" after the modernized building,
- the ability to quickly installation and relatively easy disassembly, a significant, for example, when replacing the roof structure or changes in the function and arrangement of the user interface of the building,
- high degree of prefabrication and highly accuracy of matching individual elements to the specific dimensions of the existing structure, including the possibility of using multiple types of system such as scaffoldings and temporary supports,
- the possibility of the complete recycling of disassembled components, which is part of the contemporary requirements of protecting the environment,
- relatively easy opportunity to rebuild and strengthen in the future.

From a design point of view of buildings of masonry or reinforced concrete structure are systems of slab-disc or slab-disc-bar. Properly designed, constructed and maintained objects of such kind are characterized by relatively high structural durability, which to a large extent depends on the load bearing capacity and disc stiffness of the walls and floor diaphragms and their interconnections. As time progressed, however, the natural process of degradation of the technical condition of the structure is placed, which can be accelerated in the absence of proper maintenance and the use in accordance with the technical requirements of the object. The reason for building disasters and design faults of constructions can also be environmental actions, which over the centuries of the building history often may be subject to adverse changes caused by both human activities and natural factors: changes in soil-water conditions, the impact of mining activities, faulty repairs or modernization, vandalism and terrorism or hostilities.

Wall and floor discs that do not provide further safe use of the building may be temporarily or permanently replaced or reinforced with steel - bar bracing systems, which according to the classification of Mazzolani [1], allows for the required load capacity and stability of the structure at all four levels of the engineering activities in renewed buildings i.e.: protecting, repairing, strengthening and rebuilding.

2. TEMPORARY BRACINGS

The task placed on temporary bracings is primarily to ensure security until the start and during construction or maintenance. In terms of the use purpose, steel bracings used in historic buildings can be divided into:

- provisional bracings - their use is a rapid structural intervention which would prevent the construction disaster; as long as initial load estimation and geometric conditions allow, one often uses for this purpose the elements of scaffolding system (Fig. 1).



Fig. 1. Provisional bracings of wooden roof structure of historic church, endangered by building catastrophe, with a lightweight steel bracing system [2]

- renovation bracings - are scheduled in the project of construction works organization including possible to use the support points, technology of performing works and ensuring proper and safe work of horizontal and vertical construction equipment transport; examples of realization of renovation bracings are shown in Fig. 2 and 3, and solutions of two basic forms of construction, i.e. angle strut-cantilevered and strut in Fig. 4 and 5,

- transport bracings - ensure the stability of the body of the building during its movement, an example of their use is the move of the Church of the Visitation of the Blessed Virgin Mary on Leszno Street in Warsaw [5],



Fig. 2. Renovation bracing angle strut-cantilever type of historic front wall with a height of 28.0 m (designer - Cz. Hodurek) [3]



Fig. 3. Renovation bracings strut-type of historic facade walls [4]

- bracings of custom support structures - for example bracings of mobile scaffolding platforms; example of application is the support structure of the movable scaffolding height of 28.6 m made in order to carry out the

restoration of the walls and vault of the chancel of the Basilica of St. Mary in Kraków [6].

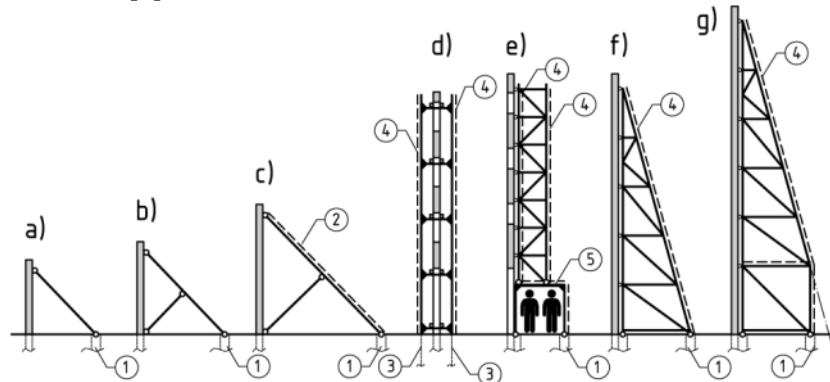


Fig. 4. Examples of design solutions of renovation bracings of angle strut-cantilevered type 1 - the temporary foundation (newly designed or used an existing one), 2 - truss or frame bracings, 3 - steel pile, 4 - truss bracing, 5 - steel portal frame

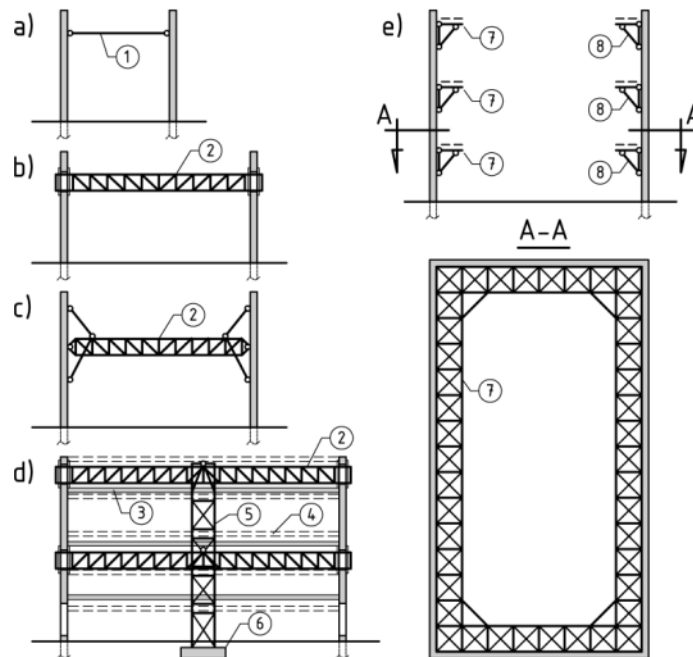


Fig. 5. Examples of design solutions of renovation bracings of strut type: 1 - strut bar, 2 - 4 - chord spatial truss, 3 - ceiling for demolition, 4 - designed ceiling, 5 - steel truss column, 6 - the temporary foundation, 7 - bracing frame, 8 - angle strut

The use of structural steel section in the form of temporary bracings and other supplementary structures is particularly useful in the conduct of construction works in the dense built-in of the old town, especially when the subject is the development of "infill" type.

This arrangement imposes contractors a series of strong restrictions, including due to the fact that the technical condition of neighbouring buildings is generally poor or very poor, and access to the construction site difficult. There is no space to arrange back office; restrictions apply, in particular, to the storage (and even unloading) of building materials. Often it is not possible to operate heavy construction equipment for lifting and horizontal transport. An additional difficulty is the need to ensure the smooth functioning of the neighbouring buildings as well as technical and communication infrastructure of the city. In such cases, the use of temporary steel structures may be the most reasonable solution.

3. STEEL BRACINGS USED FOR PERMANENT REPAIR

From ancient times until the invention of concrete and development of reinforced concrete structures, arch as a structural form of lintel or vault was crucial in shaping the structure. A disadvantage of the arch as a structural element, in particular stone or brick is its sensitivity on the level of displacement of the supports. Traditional form of repair and strengthening of the arches is the use of bracings in the form of steel tie bars located at the level of the springer. In case when the cause of damages is uneven soil settlement and damages cover a significant part of the building, it is preferable to construct bracing system consisting of slender ties and struts, which form a horizontal diaphragm providing adequate load bearing capacity of the building vaults (Fig. 6).

Steel horizontal bracings are also used for strengthening the wooden ceiling, as was the case, for example of, the renovation of the Collegiate of St. Martin Church in Opatów [8].

Repair and reinforcement coming from the sixteenth century masonry and wooden 50-meter high tower of the church in Piekary Śląskie was performed placing inside steel frame braced with vertical steel ties systems [9]. This structure, introduced into the interior of the tower, allowed masonry parts repair without removing the wooden helmet and restored tower functionality allowing you to use the tower bells.

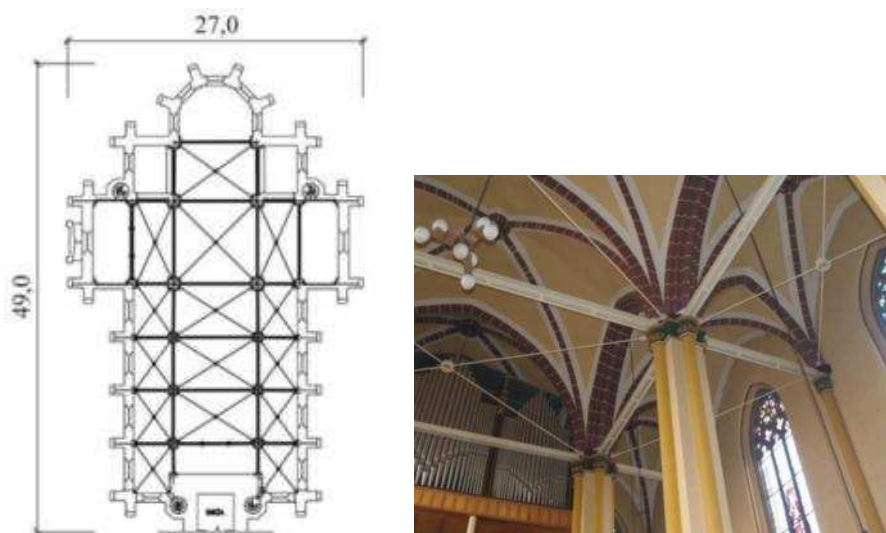


Fig. 6. The horizontal bracing at the height of the springers of the vaulting arches of neo-Gothic church [7]

Another class of applications are the bracings of vertical walls of historic buildings being under the influence of seismic and paraseismic actions. Bar bracings, usually shaped in the form of a truss, are placed in the axes of structural walls in the intercolumns or window and gate openings. In the case of absence of such possibility, bracings are placed on the surface of the wall, designing suitable anchorage. The use of steel bracings in the renovated building also creates the perfect opportunity to install collaborating seismic vibration dampers.

4. BRACINGS IN RECONSTRUCTIONS

Full architectural reconstructions are performed only in exceptional cases, such as the reconstruction after the building disaster. Partial reconstruction restoring destroyed section of building is not rare in conservation work. Application area of steel structures is partial reconstructions, which are mostly the restoring of wooden roofs, which are not generally exposed and made available to the public. Often, this reconstruction type shape a historical figure of the whole architectural group, at the same time being the landscape dominant with long-range visual impact. Steel bracings as independent elements are rarely used in the reconstruction. However, if the reconstructed portion of the building is designed as a steel structure, the natural choice of the designer is to use of the bracings of the same material. Examples of such projects include the

reconstruction of a Renaissance helm of town hall tower of the New Town in Gdansk made in the mid-50s of the last century and the roof of the Senators tower (Lubranka) on the Wawel carried out in years 2002-2003 [10] and a number of sacred building roofs throughout the country.



Fig. 7. The horizontal bracings in the steel reconstruction of the Lubranka tower roof on the Wawel (left) and a view of the object after completion of maintenance works (right) photo by P. Stępień [10]

5. CONCLUSIONS

Steel bar bracings have been successfully used in historic buildings of other than the main steel support structure. Reservations of restoration mainly do not raise the use of steel bracings as temporary items used during renovations. Advantages of steel hardenings are evident especially during the execution of the works in the dense built-up of the old town, where access to the site is limited and the poor technical condition of the neighbouring buildings hampers carrying out construction.

The use of steel bracings for permanent repairs, strengthening and reconstruction pose an interference with the historical substance of a clearly distinguishable form, material and technological performance. However, in many cases, interference with frequent absence of alternative solutions is a justified need to stop progressing damages and deteriorating technical condition of buildings affecting the safe use. Area of application of steel bracings is usually a reconstruction in the form of superstructures and

strengthening of buildings with relatively high altitudes such as high towers and roof covering of church aisles. In many cases, such formed structural system avoids the irreversible loss by protecting the most sensitive parts of historic buildings, which are usually ceilings and vaults, often decorated with polychromies of high historical and artistic value.

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ZASTOSOWANIE STALOWYCH STĘŻEŃ PRĘTOWYCH W RENOWACJI I MODERNIZACJI OBIEKTÓW ZABYTKOWYCH

Streszczenie

Wykorzystanie stalowych stężeń prętowych jest możliwe we wszystkich czterech stadiach działalności inżynierskiej przy renowacji i modernizacji zabytkowych obiektów budowlanych, tj.: zabezpieczaniu, naprawie, wzmocnieniu i przebudowie. Stężenia stalowe stanowią pomocnicze układy konstrukcyjne, które ze względu na swoje relatywnie niewielkie gabaryty przekrojów i niski ciężar własny umożliwiają efektywne osiągnięcie wymaganej nośności i stateczności oryginalnych układów konstrukcyjnych obiektu zabytkowego. Stosunkowo częstym przypadkiem zastosowań stężeń stalowych są stężenia tymczasowe służące do zapewnienia bezpieczeństwa obiektu do czasu rozpoczęcia i podczas trwania prac budowlanych lub konserwatorskich. Zalety tego typu stężeń uwidaczniają się zwłaszcza podczas prowadzenia robót w gęstej zabudowie staromiejskiej, gdzie dostęp do placu budowy jest utrudniony, a zły stan techniczny sąsiednich budynków i ograniczenia wymiarowe komplikują prowadzenie budowy. Stalowe stężenie prętowe z powodzeniem są również stosowane do wykonania trwałych napraw, szczególnie tam gdzie wymagane jest osiągnięcie dużej nośności przy stosunkowo niewielkich gabarytach przekroju, a miejsca interwencji konstrukcyjnej nie są eksponowane. Obszar zastosowań stężeń stalowych obejmuje także rekonstrukcje, najczęściej są to stalowe szkielety nadbudowy. Konstrukcja stalowa w większości przypadków stanowi tkankę różniącą się stylem i materiałem od autentycznej występującej w odnawianym obiekcie zabytkowym, nierzadko jednak jest jednocześnie racjonalnym rozwiązaniem, akceptowalnym z konserwatorskiego i konstrukcyjnego punktu widzenia.

Słowa kluczowe: stężenia stalowe, renowacja, obiekty zabytkowe, stateczność ścian, wzmocnienie, rekonstrukcja, przebudowa

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