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# SUPPORT SYSTEMS FOR WALLS IN ANCIENT BUILDINGS UNDER DEMOLITION

**Extended Abstract**

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# EXTENDED ABSTRACT

## INTRODUCTION

The purpose of this Master's dissertation is to produce a study of the temporary structures which support the walls of ancient buildings that are to be preserved after their demolition, aiming at their reconstruction.

This procedure, usually known as "façade retention" or "façadism", is a radical intervention in the sphere of building rehabilitation, applied to old buildings when the intention is to wholly or partially demolish the interior, retaining only the façade (most common) and possibly other elements, such as internal walls, staircases or cores.

Reconstruction of buildings, although an ancient practice, used to have different objectives from those of today. In addition, in the past, historical conservation and modernisation were regarded as antagonistic, which is not so today. In fact, keeping the façade has become a quite common practice, as a good compromise between architectural conservation and progress.

Generally, keeping a façade is the more expensive and time-consuming option, whether in a limited intervention or the complete demolition and reconstruction of the building. In spite of this, maintaining the façade can offer numerous advantages that are explained in this document. Additionally, there may be other reasons for maintaining façades, though they may not be regarded as advantages. Thus it can be concluded that the maintenance of façades is a practice of growing importance nowadays, and is tending to become more frequent.

## THE CONSTRUCTIVE PROCESS

The process of construction of a new building while maintaining the old façades goes through a series of phases, starting with the initial survey and ending with the construction of the new building and posterior work such as the dismantling of support systems.

It is necessary to really get to know the building and its surroundings before taking any decision about the support structures to be used and about the demolition, as only after understanding the reality of the existing situation can decisions be made over the best measures and techniques to make the building process more economical, rapid, functional and safe. With this in mind, an initial inspection includes obtaining all relevant information, such as data of the plan and its building, later alterations and interventions, and the techniques and methods used in its construction. It should also find out whether there are heritage or historical limitations and whether it is possible to change the use of the building. This inspection is complemented with a visual inspection to enable a global understanding of the structure and an analysis of such aspects as the geometry, foundations, materials and state of conservation of the building, details of its surroundings, acting loads and load paths. The initial inspection should also be complemented with a series of tests.

The buildings under study generally have walls of ordinary masonry consisting of rough stones, irregular in shape and size, often joined by mortar that give them very little cohesion and resistance. Thus, before and during the demolition work, it is necessary and good practice to consolidate and/or reinforce the structure elements that are to be preserved, in order to preserve their integrity. In addition to the different techniques for consolidating the stonework here presented, the building also needs work to reinforce windows, doorways and other possible openings, in order to avoid the appearance of cracks near these weak points and give the façade more stiffness.

Throughout the whole building process, the elements to be preserved and their neighbouring constructions are subject to various strains and should be permanently monitored so that any possible anomalies that might give rise to irreparable damage and even accidents can be detected in advance.

Once the preliminary studies and works have been carried out, the erection of the temporary support structure or the demolition work can begin. Generally speaking, the structure is erected before demolition, as a means of external support, and is done in phases, alternating with the demolitions, as a means of internal support. Generally, the erection of this structure begins with its foundations (if these exist). The next step should be the connetion to the walls of the internal and/or external linear support grids (grids collinear with the walls which strengthen them and distribute the load) to which, finally, the supporting structure will be connected.

The different ways in which this fixing can be done can be divided into two main groups - direct and indirect fixing. The former is a destructive method, in which the links are carried out in holes previously made in the wall, which are afterwards sealed with not retractable mortar. The second technique is not destructive, as it tightens the external and internal grids against the walls by linking them through openings in the façades.

The demolition is a very important phase and should be very carefully carried out since they generally take place in rundown buildings whose urban surroundings are also in poor condition. As well as limitations of space, noise and dust, great care must be taken not to cause too much vibration, either in the parts of the building to be preserved, or in surrounding buildings. Consequently, machinery that is not too powerful is used, and often resort is made to tradition demolition, bit by bit, carried out by hand, with the aid of light tools and scaffolding or cranes.

The foundations of these parts to be preserved are frequently in bad condition, and/or are not ready for the increased level of load they are to be subjected to, so that they have to be reinforced, very commonly with the use of bored piles and micropiles. The bored piles are used mostly at a lesser depth than the micropiles, though this is not necessarily so.

One advantage of the demolition of the inside of the building is the possibility of excavating the interior to make basements. In these cases, it is necessary to extend the foundations of the elements to be preserved, executing peripheral contention solutions as tieback walls, soldier pile walls, pile walls or slurry walls. Whatever the solution adopted, it is necessary to guarantee the stability of the walls before starting any work of demolition or excavation.

In carrying out the new building work, there may be two distinct situations: the element to be preserved continues to have a structural function, or it may have only a function of architectural integrity. In either case, the structures should be compatible, so that the new work does not damage the old, and so that the best use possible may be made of the building in terms of architectural value and useful space, without affecting future uses of the building and its functionality.

When the new work is completed and joined to the old, the structure use to support these elements can be removed. This dismantling of the structure must be

carefully carried out, in the inverse order to its setting up, so that the minimum amount of damage is done to the part it was supporting.

TYPOLOGY

There is great diversity in the types of support structures for walls. Every situation has its own conditioning factors, and demands a specific treatment. It is thus not easy to classify the different types of solution to be employed. The characterisation by type of the different structures is an important tool for understanding their advantages, disadvantages and applicability. Different authors offer their own classifications, while in this paper the classification used divides support structures for walls of old buildings being demolished into methods of support and types of support, these factors being somewhat related since each type of structure presents a greater incidence of a specific method.

The methods of support can be divided by the position of the structure in relation to the building, the distinction being between structures outside and inside the building and in addition structures that are mixed. In the great majority of cases the façades are the elements to be preserved in old buildings, so that support from the outside is preferable, avoiding the placing of elements inside which would make the work of reconstruction difficult. Nevertheless, the use of outside space is generally limited, or even impossible, so it should be minimized, in order to reduce conflicts with the surroundings.

The second classification considers the type of structure used, making a separation between flying shores, ranking shores, vertical shores and dead shores.

Flying shores are generally used when the method of inside support is chosen, or as part of the structure in the mixed method. They may thus be used exclusively, or in conjunction with other types of structure when the use of outside space is limited or not possible, or when it can take advantage of the proximity of points of support on other buildings or the parts of the building that are to remain.

This support transmits all the loads to the adjacent structures which support it. It is therefore dependent on their condition and strength. As this type of support relies on these elements it does not need to be connected to the ground through foundations.

This structure usually consists of straight bars, which may be frames or trusses, arranged more or less horizontally, though not necessarily so. The arrangement of these

bars may be perpendicular or oblique to the walls, whether horizontally or vertically. As they rely on compression, their angle with the plane of the wall is important. The nearer it is to a right angle, the more the mechanical capacity of the bar as well as the maximum force that can be transmitted to the support.

Consisting of bars anchored to the ground, ranking shores support the walls of the building, and are no more than a set of bi-articulated bars. When lateral support to a wall is needed, this is the simplest structural system, which is also widely used to support excavations.

This type of support, as well as being used to support walls of old buildings being demolished, is also much used for emergency support of walls made unstable by excavations or wind, due to the pace with which it can be erected.

Vertical shores consist of a set of frames placed vertically (on the strongest vertical alignments of the wall) fully supported in foundations in the ground and connected to another series of frames arranged horizontally. Generally, these vertical elements are placed on the outside of the building so as not to interfere with the works inside, and to occupy small area, not to have a great impact on the surroundings of the building, normally pavements. However, there are cases when it is decided to place this structure inside, perhaps later to become part of the final structure, or even on both sides of the façade.

This structural system can de applied in isolated walls or to shore up the façades of small buildings whose interior is not demolished.

Dead shores consist of a structure with two alignments of vertical frames, shored by a series of horizontal bars at the level of each floor (at least) with or without diagonal bars. The main (vertical) frames bear the loads transmitted by the secondary (horizontal and diagonal) frames and transmit them to the ground through the foundations. Although the forces transmitted to the foundations are comparatively easy to absorb, the two vertical frames should have a common footing, or, at least bases, linked by foundation beams, to prevent differential settlement.

The preference for this system of structures may be due to the fact that it is the only self-bearing one, which, as well as the fact that it can easily be adapted, means that it can be applied to any type of wall, regardless of its geometry and state of conservation. In addition, this versatile structural system is the one that grants easier access to work zones (inside the building) for the circulation of machinery, equipment and personnel.

Another advantage of these structures is the possibility of locating inside the building worksite installations such as bathrooms, dormitories and offices, making good use of space, which, in urban areas, is extremely important.

It may be said that the great limitation of this system is the occupation of an area outside the façade when it is being erected, which may mean that it is sometimes not permitted in urban zones. For the same reason, diagonal bars at ground floor level are usually dispensed with to allow the passage of pedestrians or even vehicles. This part of the structure then needs to be reinforced.

Dead shores and flying shores are the most used, often being employed together, especially in framed structures with corner shores. The geometric definition of a building and its surroundings decide the best choice, together with the quest for speed, safety and economy.

Another type of structure that is applied together with the support for the walls is temporary roofing. The purpose of these structures is to protect the inside parts of the building that are not to be removed, and that may be damaged by rainwater, such as staircases and wooden floors, walls and ceilings. Besides, this has the advantage of enabling normal work to continue even in bad weather.

On the other hand there are some disadvantages. Among these, there is the difficulty of reaching the inside with lifting equipment such as cranes, the reduction of height inside and the increased costs of the work due to the use of this type of structure which, in other cases, is quite unnecessary.

## DESIGN

As the building is demolished, the support structure is gradually taking over the loads which were previously borne by the interior of the building and which will later be transferred to the new structure. Meanwhile, the provisional structure is subject to various loads, for which it must be designed and for which it must observe the safety demands of the Ultimate Limit State and Serviceability limit state. To decide on the correct design of the structure, it is necessary to identify and quantify these loads, i.e. imposed loads, permanent and variable actions

As permanent actions there is the weight of the support structures themselves, of the façades, and, possibly, the weight and other permanent load of other elements to be preserved, such as office containers.

As variable actions one can consider the actions of wind and earthquake, vibrations, accidental accidents (collision of cranes or vehicles) and other actions such as the weight itself of the wall to be supported, or a percentage of this, due to the divergence from the vertical, or even loads coming from parts of the building which have not been demolished, or neighbouring buildings that need to be shored.

Since these are temporary structures and therefore intended to last a relatively short time, much less than return periods normally expected, the action of earthquakes is not normally considered. However, it may need to be taken into account, for example, in cases where the risk of potential earthquake damage is very high.

It is not easy to quantify the effect of vibrations, caused by the demolition or movement of personnel during reconstruction. Generally, these actions are not significant and are not taken into account, but it must be borne in mind that even if they are not very relevant in terms of stresses, they reduce the stiffness of the structure, which means they cannot always be ignored. If the area is very much subject to vibrations, as in special situations, such as near Underground or railway trains, or the presence of industries with equipment that produces vibrations, then these should be quantified.

As well as deciding on the correct design of the structure, it is essential to ensure the correct design of the connections, both of the provisional structure to the preserved walls, and of these to the definitive structure, so that these do not create a weak point. Similarly, it is not enough to fit connections of great strength: it is also necessary to ensure that they do not break through crushing / pulling out of the concrete or masonry, or through the tearing out of the bolt, either where the anchorage resin meets the masonry, or where the bolt meets the anchorage resin.

The determination of the mechanical characteristics of the walls to be supported is a useful means to deciding on the design of these connections and support structures. Since the characteristics of shape and construction of walls are relatively variable, depending on the type of masonry of which they are built, on their state of decay and the repairs they have received, their mechanical / structural behaviour is also very varied, and special methods are needed. These can be divided into direct and indirect methods; the first have an important disadvantage, owing to their essentially destructive nature and to the large sizes of the samples, which limits the number of tests done, and thus the representativeness of the results.

The creation of structural models enables the estimation of the stresses to which the structure will be subjected, and thus its design can be decided. However, it is never possible to cover all possible situations of support for walls, as each case is different and needs a specific structural model. Nevertheless, one tries to cover the maximum number of situations, establishing a structural model for each type of support operation, using a typical façade to support and subject to a typical action. The aim is not the design of the structures but rather to be able to analyse and compare, qualitatively, the way different systems of support react to the same type of action.

## COMPARATIVE STUDY

The comparison of the different types of support structure can become an important tool in the process of deciding the choice of structure to employ, depending on the priorities of whoever opts for this process. Thus, one tries to decide on the best structural solution from different points of view.

The system whose erection is generally quickest is the flying shores as it is a very simple structure, consisting of a reduced number of frames supported only by their ends, without the need for foundations. However, as it is applied in phases, in the end it takes longer to put up and take down than the other systems.

Flying shores are also those that generally cause most impact on the course of the works, since they are usually set up inside the building, spreading a set of frames through the heart of this space, which conditions the movement of equipment and materials. Besides this, it may become necessary to have short interruptions at the beginning to put up the shoring and continue with the demolition, and, at the end, to remove a new level of frames and thus advance to the building of another floor.

Structures set up outside are those that have the greatest impact on the surroundings, this impact increasing with the size of the area they occupy. The impact may be visual and on the circulation of people and vehicles. One way to reduce the visual impact is to try to hide or disguise the support structure, with a net or other material (perhaps carrying advertisements). With dead shores, the impact on circulation can be reduced by creating open spaces that permit the circulation of people or even vehicles through them.

It is impossible to say, at the outset, which is the best solution from an economic point of view. They economy of a solution includes various factors that need to be

weighed and that vary greatly according to the chosen solution, local factors and their resulting impacts.

Among other factors, the most economical solution depends on:

- the cost of the supporting structure;
- the cost of setting up and taking down the supporting structure and the construction of its foundations (speed, ease of execution, demands for labour and specialized machinery);
- effects during the course of the works (loss of time and restrictions on the use of certain building techniques and equipment);
- effects on the surroundings (imposed restrictions, the need for measures in the surroundings, such as putting up systems to protect people and vehicles and to enable normal traffic).

In an economic analysis of the wall supporting structures, a comparison should also be made of the traditional systems employing metal frames with modern systems of lightweight girders that can easily be fitted together. Weighing up the different variables, one may conclude that for periods shorter than a year and a half, it is worth hiring such a system, and for repeated use, it may even be worth buying such equipment, in spite of its high initial cost.

The return of these systems, in these respects, can be more or less improved, according to such aspects as:

- the experience acquired in the restoration works that are carried out;
- the adaptability of the structure for different support works;
- the possibility of dividing the structure into parts that can be transported and easily erected in the next work;
- the use of modern systems, with variable lengths, that can
- be fitted together, are adjustable and easily put up and taken down, producing good results in terms of time and labour.

## CASE STUDIES

As it was shown in this document, the extensive variety of buildings whose façades are retained can be rebuilt by many ways. The aim of this chapter is to give illustrated descriptions of facade retain situations, giving a detailed insight into each scheme and the different techniques used to solve the various technical problems.

Considering the restrictions that can be found in different works, the engineer should try to find ways of avoiding them, with minimal consequences. In the first case study, one can see how the support structure of the lateral facades could not occupy a position outside the building and had to be placed in the interior, which led to a loss of valuable space in the basements.

In different cases some details may appear that require from the engineers intelligent solutions to solve them. An example is the solution adopted for the retention of the rear facade of the building that will be the new headquarters of BIG, with the suspension of the facade and of the support structure with another structure built with micro-piles and steel tubes.

The analysis of case studies can also show how in different works, or with different designers, the actions considered and their quantification may vary, denoting a lack of regulation in this area.

## CONCLUSIONS

Initially, it was concluded that nowadays, the rehabilitation of buildings, is an issue with growing importance which leads to an increasing use of interventions with preservation of old parts that are, great majority of cases, the façades.

After an analysis of the constructive process, could be concluded on the importance of certain procedures such as: the completion of preliminary studies before making any decision; consolidate the retained parts; constant monitoring of the building and neighbouring buildings.

As it was shown, there are many configurations of support structures and that its typological characterization is an important tool for understanding of its advantages, disadvantages and applicability.

Regardless of the actions taken (varies with the building and its surroundings and also with the designer), is an essential care scaling of the structure of restraint and also of connectors.

The retention of facades, although it is already a fairly common practice, is a matter on which not much is written and lacks studies that may develop the state of the art. The lack of literature is also accompanied by lack of regulation, both for the project and for monitoring the implementation of works.