

MODERN METHODS OF MASONRY ARCHES STRENGTHENING

Arches were an architectural invention used throughout the ancient time. Arches were used for their stunning visual design and more importantly to create support for many of ancient buildings and monuments. Arches were also used in buildings because of their strength and support capabilities. Because of the curved design of the arch, it allows structures to pass weight from above, down to the ground through piers that support the arch. Additional forms of arches are vaults and a barrel vault. A vault is a long arch that makes massive structures possible. These types of arches allowed the ancient architectures to build massive buildings compared to traditional masonry techniques that were limited and were not able to withstand a huge amount of weight.

One of the forms of historic preservation is transforming old buildings into more modern facilities while keeping their historic architectural value. Historic preservation is highly beneficial to the environment as the renovations save energy resources spent on building materials, equipment, transportation, tools, and reduce the harms of construction waste that negatively affect the environment. The restoration of old and historic buildings also increases the local worth.

Strengthening of masonry arches can be achieved by means of several techniques. Traditional techniques for strengthening vaults and arches have been widely used. The common techniques found in literature are the use of steel bars or stirrups to increase confinement of masonry arches, the introduction of ties at the arch impost, the use of reinforced concrete hoods, the construction of internal spandrel walls to prevent thrust, the application of steel profiles at the arch intrados and the injection of cementitious mortar. Due to the aesthetic incompatibility and to the extra self-weight and rigidity that these techniques could added to the structure, they are no longer used and are being replaced by new techniques.

Strengthening of masonry arches by means of composite materials is one of the most innovative techniques that can be used to increase or restore the structural capacity of these structures. The technique offers advantages over traditional reinforcement methods such as it does not increase the mass of the structure, does not significantly change the rigidity of the arch, does not alter the static arrangement of the arch in service conditions and finally modifies the arch collapse mechanism.

The steel bars or plates used for reinforcement are typically made from high-strength materials such as stainless steel, carbon steel, or high-strength alloy steel. They are designed to resist the tensile forces that can cause cracking or collapse in the arch. The reinforcement can be added to the arch during construction, or as a retrofitting measure, and can be installed in various configurations depending on the design requirements.

Post-tensioning is a popular method for strengthening masonry arches because it can provide a high degree of strength and stiffness without adding significant weight. The high-strength steel cables used for post-tensioning are typically made from high-tensile steel wire or strand and are designed to resist the tensile forces that can cause cracking or collapse in the arch. The cables are typically installed in a configuration that follows the lines of stress in the arch, and are anchored at each end using a special anchorage system.

Carbon fiber sheets used for arch reinforcement are typically made from high-strength carbon fibers that are embedded in a resin matrix. The sheets are lightweight and flexible, and can be cut to fit the shape of the arch. The sheets are bonded to the surface of the arch using a high-strength epoxy adhesive. Carbon fiber reinforcement can be used in combination with other strengthening methods, such as steel reinforcement or grouting.

Grouting is a method of strengthening masonry arches that involves injecting a fluid material, such as grout or resin, into the masonry to fill voids and improve load distribution. Grouting can be used to repair cracks and prevent further movement in the arch. The grout or resin is typically injected into the masonry using a pressure injection system, which forces the material into the voids and spaces within the masonry.

Adding support beams or columns adjacent to the arch can help distribute the load and prevent further movement or cracking. The beams or columns can be made from a variety of materials, including steel, reinforced concrete, or timber. They can be installed in a variety of configurations, depending on the design requirements and the condition of the arch.

In addition to these methods, other techniques such as masonry stitching, which involves using metal ties or rods to reinforce the masonry, or shotcrete, which involves spraying a layer of concrete onto the surface of the arch, can also be used to strengthen masonry arches.

It's important to note that the selection of the appropriate strengthening method depends on several factors, including the age and condition of the arch, the type of load it must bear, and the available budget. A structural engineer should be consulted to determine the most appropriate method for each individual case.

References

1. A. El-Safty and M. Al-Deeb (2018) "*Rehabilitation and Strengthening of Historic Masonry Arches*".
2. G. Manfredi, G. C. Maffei, and G. Vitaliani (2022) "*Strengthening of Masonry Arches Using Carbon Fiber Reinforced Polymer Laminates*".