APPLICATION OF SMPM TECHNIQUE IN THE RETROFITTING OF HISTORIC BUILDINGS

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ABSTRACT :

China is an ancient civilization with a long history and around the country there located numbers of historic buildings, which have been concerned and protected by the society and government. In view of the special nature of these buildings, fire resistance, environmental, economic and other aspects of special requirements must be meet as well as the safety, reliability and the reservation of their historic characters in the maintenance process and reinforcing construction of the building structure. The retrofitting technique of composite layer of high-strength steel stranded wire mesh and polymer mortar(SMPM) is a brand new one of structural strengthening with the advantages of high-strength, environmental and resistance to fire, corrosion and ageing. This technique overcomes various shortcomings of the existing ones, especially for the historic buildings. In this paper, applications of this technique in the maintenance process and reinforcing construction of historic buildings are introduced, which shows impressive effects and achievements.

KEYWORDS: historic building, strengthening, SMPM, fire resistance, “green” technique

1. INTRODUCTION

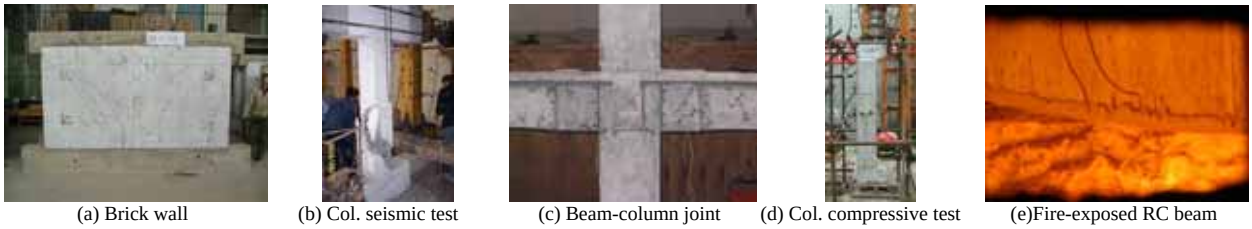
The retrofitting technique of composite layer of high-strength steel stranded wire mesh and polymer mortar(SMPM) is a brand new one of structural strengthening with the advantages of high-strength, environmental and resistance to fire, corrosion and ageing. This technique overcomes various shortcomings of the existing ones. Recently, experimental studies on this technique were carried out by Institute of Earthquake Engineering(IEE), China Academy of Building Research(CABR), and impressive achievements were obtained, which led to several applications in the reinforcing construction projects. The studies were supported by Beijing Municipal Commission of Science and Technology (Project No. H030630210430).

There are several disadvantages in each of existing structural strengthening methods such as strengthening with reinforced concrete, externally bonded steel frame, fiber reinforced polymer(FRP) etc. Take the reinforced concrete strengthening method for example, it is able to improve load-carrying capacity and stiffness of the structural member, but it is also greatly increase the deadweight with reduction of the architectural space. Although the externally bonded steel frame method has the advantage of more convenience in the construction process, it is not in accordance with the trend of “green building”, because the structural adhesive bonding material for the steel plate and the original structural member consists of organic material which can cause pollution to the indoor environment and threat to the health of the constructors as well as the problems of durability, fireproofing and so on. The similar technical problems also exist in the FRP method.

The procedure of the SMPM technique is: Firstly, remove the loose concrete surface of the strengthening zone; then, lay down the steel stranded wires, then draw them to some degree of tightness and fix them with bolts;

finally, apply interfacial cementing layer and the polymer mortar. In this technique, the steel stranded wires shares the tension force with a greater tension strength than reinforcing bars. The polymer mortar has the advantages of high degree of density and bonding strength as well as preferable penetrability. This material is also resistible to chloride and some other chemicals. Therefore, the polymer mortar is able to effectively protect the steel stranded wire mesh and the original reinforcing bars and prevent the inner concrete from carbonization. At the same time, the polymer mortar can bond well the steel stranded wire mesh to the original structure to form an overall structure so that they can work together with coordinative deformation to enhance the load-carrying capacity and stiffness of the structural member.

In recent years, a series of experimental studies on SMPM technique were carried out, which include the investigations to explore the behavior of strengthened brick walls, RC beams and beam-column joints as well as the behavior of fire-exposed RC beams in high temperature. Experimental tests were also designed to investigate the compressive and seismic behaviors of RC columns strengthened with SMPM. The experiment results showed that there were significant effects to the structural members after strengthened. The ductility of the structural member was also improved obviously. Moreover, excellent performance was found when the strengthened member was exposed to fire in high temperature.



(a) Brick wall (b) Col. seismic test (c) Beam-column joint (d) Col. compressive test (e)Fire-exposed RC beam

Figure 1 Experimental investigations on structural members strengthened with SMPM

2. STATUS QUO OF HISTORIC BUILDINGS IN CHINA

China is an ancient civilization with a long history and around the country there located numbers of historic buildings. These buildings are a huge wealth, some of which witnessed important figures and major events in the past and left plenty of information about our history. For example, the Beijing royal gardens, ancient capital buildings and the National Government building in Nanjing, Old western-style buildings in Shanghai, Southeastern Asia style buildings built by overseas Chinese in south China, sites of embassies and consulates in early times, puppet Manchuria buildings in northeast China, the top 10 buildings in 1950s and so on.

These historic buildings have been always concerned and protected by the society and government. Especially in recent years, with the rapid development of the economy, the government's and general public's consciousness of protecting historic buildings has further increased, and relative laws and regulations were enacted. In some districts, technical codes or specifications have been or are being made for these buildings of different kinds. It is believed that protective strengthening or rebuilding of the historic buildings will be a hot topic in the retrofitting engineering field.

Generally, historic buildings have a long history and were built with various structures and architectural styles. And most of them can not meet the requirement of the seismic performance in the modern sense. Different with common retrofitting projects, not only the security of the structure is required, but also the original feature of these buildings should be reserved as to keep the historic information contained in them, especially for those with great values in the architectural history. In the mean time, some of the buildings are expected to be used for modern regular service after rehabilitation. The study and application of SMPM technique provide a reasonable and reliable approach to the strengthening and maintenance of historic buildings.

3. APPLICATION AND ADVANTAGES OF SMPM IN THE RETROFITTING OF HISTORIC BUILDINGS

Compared to the existing strengthening techniques, SMPM has the advantages as follows:

1) The investigations showed that SMPM technique was able to improve efficiently the load-carrying capacity of RC beams, slabs, columns and the brick walls, especially for the beam-column joints, which the existing method could not well strengthened. In the mean time, the rigidity of the structural members was able to be improved for some degree.

2) For the materials, no pollution was found to the environment, which can cause harm to people, so it is in accordance with the trend of "green building".

3) The materials demonstrated similar performance with reinforced concrete. The polymer mortar has the advantages of well bonding, impervious to water and chloride ions, resistant to crack, fire and corrosion etc.

4) Excellent behavior was found when the strengthened member was exposed to fire in high temperature. No additional fire resistance measures are need, so the construction and maintenance costs will be reduced.

5) There are little increment of cross-section and deadweight in the structural members, so that the architectural space and appearance and its function are not affected.

6) The construction technique is relatively simple so that it is possible to make the retrofitting work more efficient and construction period shorter as well as fewer disturbances to the surroundings.

The primary purpose for structural rehabilitation is to ensure the security and reliability of the structure. In view of the construction time and technology, there are a variety of potential risks in historic buildings' structure; and non seismic fortification is also the fatal security risk for all these buildings. So solving these problems should be top priority for all historic buildings. In addition, the buildings should have the capability to effectively resist to some natural disasters such as fire. Green environment is the common demand for all the residents in our planet in the era of globalization, which demonstrates "people-oriented" concept together with seismic issues. The protection of historic buildings should inheritance predecessor's essence of the idea of harmony between human and nature. Therefore, there is no doubt that taking "rebuilding it as it was" as the principle for the strengthening of historic buildings. In the process of strengthening, less defeature and influence of their function should be made under the technical feasible condition. On the other hand, the economy and later maintenance costs should be considered as an important factor in the retrofitting engineering.

From the discussion above, it is found that SMPM technique is able to perform excellent behavior in the retrofitting of historic buildings. It can effectively preserve the external appearance of the buildings and exceeds the existing techniques in several aspects such as seismic performance, non pollution to the environment, resistance to fire, economical and so on. Application of SMPM in historic buildings has a large proportion in the completed projects, which shows that this technique has obtained supports from both technical and policy decision terms. With the further research and increased promotion efforts, there will be an increasingly widespread use for this technique in the retrofitting engineering.

4. EXAMPLE PROJECTS

4.1 Xiamen Zheng Chenggong Memorial

Zheng Chenggong Memorial is in Gulangyu Island, Xiamen (a city in south China). The main building with a western style was built in 1932, and was a private villa previously. In year of 1962, it turned to be the Memorial

and was protected by the local government for its historic value. This is a four-story masonry building, and has a cast-in-situ RC floor system. After its more 70 years' service, significant quality deficiency was found in the main structure. According to the analysis and survey report, it can not meet the requirement of the seismic fortification of Intensity 7 in Xiamen; even in the regular service condition, certain security risks also exist. For the strengthening of this historic building, experts believe that the existing methods can not satisfy the demand for "rebuilding it as it was" as well as fireproof and environmental problems. However, SMPM technique was able to solve these problems and improve the load-carrying capacity of the structural members. So, in the project, SMPM was applied to the strengthening and rehabilitation of the brick walls and part of the concrete beams and slabs.

Figure 2 Xiamen Zheng Chenggong Memorial

4.2 Zhongshan Nanyin Theater in Xiamen

Located at Zhongshan Park, Xiamen, Zhongshan Nanyin Theater has a history of about 100 years(Nanyin means a traditional opera in south China). Unfortunately, as a result of the poor maintenance and management over the years, a variety of problems were observed such as corrosion of the reinforcing bars, concrete cover peeling in columns, obvious cracks in beams and slabs as well as the brick wall erosion caused by humidity. Some of timber members were also found in decay. The seismic detailing and performance of the structure can not meet the requirement of the current Chinese code. On the other hand, there have been several alterations up to now, which made the main structure more complex and force transfer system more disordered. The Nanyin Theater is expected to be a public place for theatrical performance, so higher fireproof performance is required for the structure. Considering the Nanyin Theater is a historic building with an architectural style which exhibits the typical culture in south China, the appearance of the building shall not be changed or broken when strengthening. After analysis and feasibility study, several strengthening methods were used in which SMPM technique was strongly recommended in the strengthening of beams and slabs in the second floor and beams and columns in the side corridor.

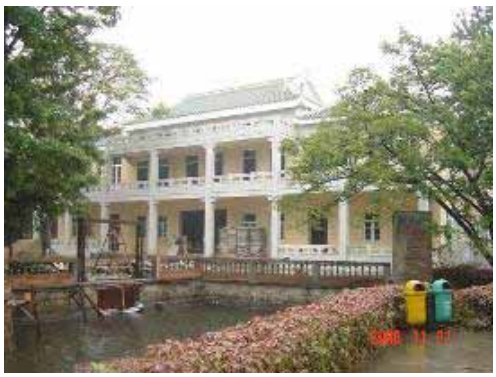


Figure 3 Zhongshan Nanyin Theater

4.3 The National Government Supreme Court Building in Nanjing

The National Government Supreme Court building in Nanjing, built in the early 1930s, is one of the sites under state protection for key cultural relics. Because of the limitation of the construction technology at that time, the structure can not satisfy the requirements of the current service. According to the survey report by Southeastern University of China, there was a significant shortage of the load-carrying capacity and seismic detailing of the walls in the first and second floors. So to ensure their continuing service, all these walls need to be strengthened. The utility of the SMPM technique in this project has been proved by experts, Jiangsu Provincial Earthquake Resistance Office.

Figure 4 The National Government Supreme Court Building in Nanjing

4.4 Beijing Workers' Gymnasium

Beijing Workers' Gymnasium, located at the Gongti West Road in the Chaoyang District, Beijing, was founded in 1959. It is one of the top 10 buildings in 1950s in China. It is a frame & shear-wall building with total covered area of 40200m^2 and the height of 26.8m. It was designed by Beijing Institute of Architectural Design(BIAD), and the structural design mainly followed the former Soviet Union code "Design Standard and Technical Code for Concrete and Reinforced Concrete Structures"(HnTy123-55) without consideration of the seismic action. The material properties, structural details, seismic fortification and other aspects of this building can not satisfy the provisions of the current Chinese codes. Also, the structure can not meet the requirements of the regular service because in the detection injuries and ageing were found in many parts or components of the structure after its almost 50 years' service. Taking various factors into account and comparing several commonly used strengthening methods, finally SMPM technique was adopted for the strengthening of the RC beams and slabs whose load-carrying capacity were inadequate.

Figure 5 Beijing Workers' Gymnasium

At the beginning of this engineering, construction technique and acceptance standard were developed for this

project by relative organizations joint with IEE, CABR. In the mean time, more detailed operating instructions for construction procedure were put forward, and technical indicators and measures were specified and the key quality control items of the construction were generalized as the main contents of quality assessment and acceptance. At present, this project has been completed and the construction technique and acceptance standard were verified, based on which Beijing local standard for SMPM was made and has come to the stage of review and publication.

5. CONCLUSIONS

The SMPM strengthening technique overcomes various shortcomings of the existing ones. It has been applied to the strengthening and maintenance projects of historic buildings, which demonstrated characteristics of high strength, fireproof, non-pollution and so on. In the recent years, experimental studies were carried out by Institute of Earthquake Engineering, CABR, and significant achievements were made as well as the formulation of local specification for construction and acceptance of SMPM strengthening technique. With the further research and improvement of design and construction standards, the SMPM technique is expected to play an important role or replace some existing strengthening methods in the field of retrofitting engineering, especially in the strengthening and maintenance projects of historic buildings.

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