Application Research of Modern Technologies on Ancient Building Conservation

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Abstract. Ancient buildings are cultural heritage entities with considerable uniqueness and irreplaceability. The existed ancient buildings are also important sources for secondary art creation in modern times. However, with the development of urban underground transportation and the occurrence of some disasters, the preservation of existing ancient buildings has become a problem. This paper focuses on several modern techniques, i.e., the initial modeling of ancient buildings, the later repair of ancient buildings, and the GFRP laminated rubber bearing technology used in the process. The knowledge obtained and analyzed from existing studies are presented to demonstrate why new technologies such as 3D laser scanning technology and GFRP laminated rubber bearings can be used for the conservation of ancient buildings. The research results can be used for better protecting of ancient buildings.

Keywords: Conservation of ancient buildings, Modern anti-vibration technology, GFRP laminated rubber bearing, 3D laser scanning technology.

1. Introduction

Modern building technology has brought significant changes to lives of people, promoting a huge leap in living conditions while also bringing some negative effects. As one part of urban transportation, the subway connects several functional subdivisions of the city, among which are also cultural reserves and ancient architectural complexes. These ancient buildings witness long history of China and have irreplaceable and irrecoverable characteristics. Because of these characteristics, the preservation of ancient buildings needs to be taken seriously and will become an essential development direction for future cultural construction in China.

The Bell Tower was built in 1384, the 17th year of the Ming Emperor Hongwu reign, which is the largest and best-preserved of the existing bell towers in China. It is located in the center of Xi'an city, under which crosses two important metro lines in Xi'an - Line 2 and Line 6. The bulk of this bell tower was made of brick and wood. However, the mechanical properties of wood are often related to durability, as the vibrating loads from rail cars in the subways act on wood members, and such vibrations can significantly affect the lifetime of wooden structures. Vibration is generally recognized as one of the seven major public hazards in engineering, and the vibration of surrounding buildings caused by rail transportation is also more intense due to its high speed, high load and long duration compared to surface transportation [1]. The vibration of subway has a great impact on ancient buildings. Hao and Duan proposed that the foundation isolation structure designed with GFRP laminated rubber bearing has about 60% reduction in acceleration response and shear response compared with the seismic structure, which shows the good seismic isolation performance of the isolation structure designed with GFRP laminated rubber bearing [2]. The comparison of data through experimental analysis reveals that new materials in modern building technology can reduce the impact of urban rail traffic on ancient buildings. In this paper, we compile the existing results of ancient building conservation and discuss the improvement of modern architecture, modern building composition, modern building construction, modern building vibration resistance, ancient building vibration resistance and the application of new materials by analogy with the vibration resistance measures of Xi'an Bell Tower, Shanghai Hongqiao International Airport and other modern buildings. Through experimental data and existing examples, modern building technology can be better applied

to ancient buildings to provide reference data for the use of GFRP laminated rubber bearings to reduce vibration and earthquake damage to ancient buildings. Some of the ancient buildings in China are still standing on the earth through the vicissitudes of time, and some of them are finally destroyed by disasters. Therefore, the protection of ancient buildings cannot be delayed.

2. Effect of Vibration on Ancient Buildings

2.1. Effects of vibration on wood structures

Unlike the medieval castles in Europe, most of the ancient buildings in China are wooden structures. However, because the durability of wood is affected by various factors, its poor durability makes the existing wooden structure ancient buildings in different degrees of deterioration. The bell tower in Xi'an is the mortise and tenon structure as shown in Figure 1 [3]. The mortise and tenon, as the important energy-consuming component of the main wooden structure, has a great impact on the seismic performance of ancient buildings. The natural aging over time also makes the mortise and tenon structure fragile, which makes the already unstable ancient buildings even more fragile.

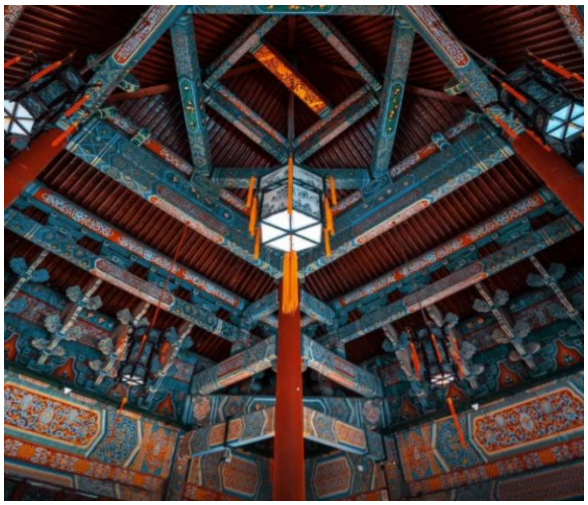

Figure 1. Mortise and tenon structure of Xi'an Bell Tower [3]

2.2. Vibration resistance of wood structures

Material aging, wind erosion and insect damage have been destroying the ancient buildings step by step. In the dynamic analysis about vibration, Zhang proposed in terms of the structural layout, special components and structural measures in traditional wood buildings, to explore their seismic concept and design ideas [4]. Research shows that: ancient buildings using wood structure are simple and regular in plan layout, the symmetrical arrangement of the column network of wood structure ancient buildings, plane and vertical stiffness uniformity, strict restrictions on the house aspect ratio and height to width ratio, the selection of structural layout schemes in line with the current seismic concept design principles. In the wooden structure, gaps usually exist between the mortise and tenon joints, and the wood will slide if it is not continuous, so the ancient building will face the threat of collapse over time.

3. Three-dimensional Laser Scanning Modeling Technology

The first step in the conservation of ancient buildings is the determination of conservation methods, to develop a suitable conservation method for ancient buildings. Engineers must have a detailed understanding of the status of the target ancient buildings. Traditional engineering measurement methods have large workloads and long working hours, which are affected by the environment. Therefore, in order to avoid the uncertainty brought by the long working hours that lead to the construction cannot be carried out and the impact of the existence of objective errors in traditional

measurements, the use of modern technology 3D laser scanning modeling technology can effectively reduce the above negative impact. 3D laser scanning modeling technology process is shown in Figure 2 [5]. 3D scanner at a distance from multiple angles scan ancient buildings, respectively, in the computer internal alignment of special points, roughly form a three-dimensional model, and then through the basic data of ancient buildings to refine and optimize the rough model to get the overall ancient building point cloud data map, and then manual repair so as to get an accurate three-dimensional ancient building model. After the model is established, the builder uses the model to analyze and determine the appropriate conservation and repair methods for the building. Since the modeling can be done without the constraints of time and space, the model allows more scholars around the world to propose their own ideas for the conservation of ancient buildings and to accurately develop repair plans, thus bringing into play the greatest effectiveness in the conservation of ancient buildings.

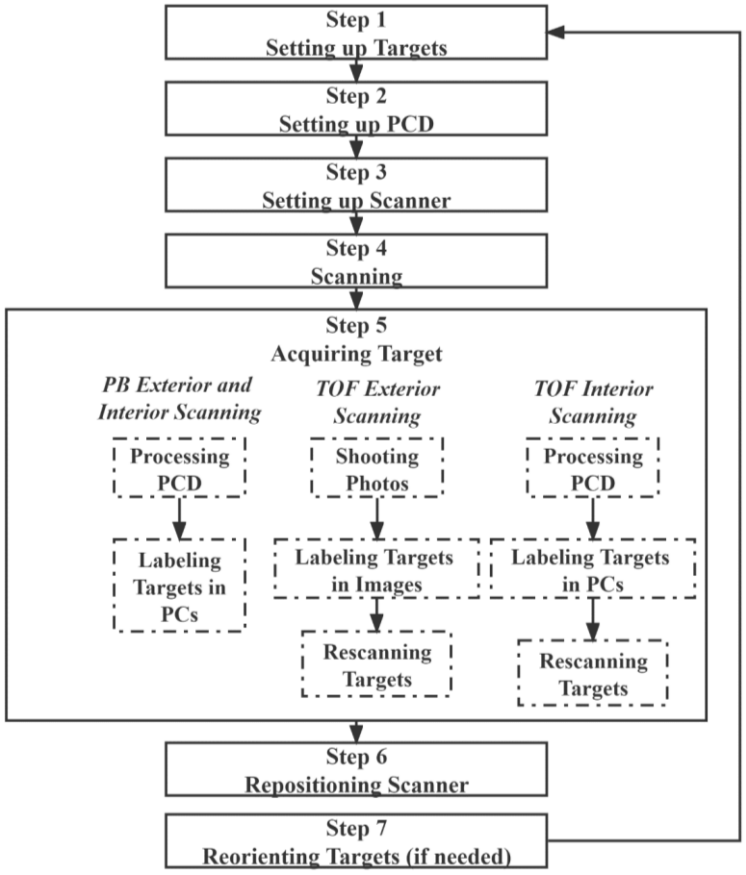

Figure 2. 3D laser scanning modeling technology process used in the project of Weiyuan Ba Ling Bridge [5]

4. Anti-vibration of Ancient Buildings by using GFRP Laminated Rubber Bearings

4.1. Vibration isolation performance of GFRP laminated rubber bearing

As a new vibration isolation material, GFRP laminated rubber bearing can be applied to ancient buildings that need vibration protection to reduce the impact of vibration and earthquake on ancient buildings. The structure of GFRP laminated rubber bearing is mainly made of thin layers of rubber and reinforcing steel plates vulcanized, which bonded to each other as a vibration isolation block. Tao and other scholars use the time analysis method and the finite element software Midas-GTS to establish a two-dimensional model [6]. The seismic motion is treated as a time-varying process, and the underground structure and the surrounding soil medium are considered as a common force

deformation of the whole, by inputting Kobe waves of Hanshin seismic records with different peak sizes at the bottom of the bedrock horizontally and vertically at the same time, under the premise of satisfying the deformation coordination conditions. The changes of displacement, acceleration, stress and strain of the structure and soil medium before and after setting the bearing are calculated respectively, and the seismic isolation effect of the seismic isolation bearing on the underground structure under the actual earthquake is analyzed. It was shown that GFRP laminated rubber bearings performed well in vibration isolation of subway. Hao also conducted a related study as shown in Table 1 [7].

Table 1. Comparison of structural periods before and after seismic isolation measures [7]

Numble	T1/s	T2/s	T3/s	T4/s	T5/s
Traditional measure	0.456	0.433	0.388	0.132	0.126
GFRP measure	1.61	1.549	1.318	0.269	0.244

Table 1 shows that GFRP laminated rubber bearing has obvious effect of extending the cycle compared with traditional vibration isolation technology, and the extension of the cycle of ancient buildings can greatly reduce the vibration damage to ancient buildings and help improve the safety of buildings. Its excellent vibration isolation performance is also used in the ancient building vibration resistance is one of the important bases.

4.2. Application of laminated rubber bearing

GFRP laminated rubber bearing has excellent seismic isolation characteristics, its excellent seismic isolation characteristics can greatly reduce the impact of underground traffic vibration on the building. Laminated rubber bearing seismic is an emerging technology in structural seismic technology, which is used to extend the system period of seismic isolation structure by using seismic isolation technology to "isolate" the superstructure and foundation of the building and absorb the seismic energy, so that the seismic intensity of the superstructure can be reduced, to achieve the effect of softness and rigidity [8]. In Shanghai Hongqiao International Airport, China, there is an important subway line connecting Shanghai city under the runway, which the subway line works uninterruptedly, the vibration of the subway will be continuously transmitted to the airport runway, and the airport has aircraft taxiing in the runway every moment. This is very unfavorable to aircraft taxiing. For civil aviation safety flight, aircraft take-off is one of the important links, and any small vibration or error in this link will bring a lot of safety hazards. China Chinese Engineer Liu Wujun proposed to use laminated rubber bearings under the airport runway to mitigate the adverse effects of subway train vibration on the aircraft.

4.3. Laminated rubber bearing applied to Xi'an Bell Tower

Xi'an Clock Tower and Shanghai Hongqiao International Airport have similar characteristics, both are located above the subway, and both buildings are adversely affected by vibration. The amplitude of radial vibration caused by ground traffic vibration at the same measurement point was found to be larger than that of tangential vibration [9]. If the bell tower in Xi'an does not have good vibration isolation and anti-vibration measures, due to the special characteristics of its wooden structure, the mutual sliding and extrusion between the mortise and tenon will make the mortise and tenon structure loose. The self-vibration frequency of the wooden structure of the ancient building considering loose mortise and tenon connections is lower than that of the intact structure, and the self-vibration frequency of the model decreases significantly with the increase of the residual damage of the mortise and tenon connections [10]. The use of GFRP laminated rubber bearings can extend the building cycle and provide a good solution for the vibration resistance of ancient buildings. At the same time, because of the special physical structure of rubber and laminated steel plates, GFRP laminated rubber bearing has good support performance, and less material can be used to support the upper load during construction, thus reducing the economic cost. According to the study, the vertical stiffness degradation of the bearing has less influence on the bearing shear deformation and the interlayer

displacement of the superstructure [11]. The good anti-vibration effect ensures that the Xi'an Bell Tower can reduce some damage in terms of vibration and prolong the life of the ancient building.

5. Conclusion

This paper introduced the LIDAR-based point cloud modeling technology and GFRP laminated rubber bearing technology applied in the process of ancient building restoration. Since vibration as one of the most affected factors of ancient buildings. The GFRP laminated rubber bearing mentioned in this paper has better vertical bearing capacity and less horizontal stiffness than the ordinary vibration bearing or technology, which can greatly enhance its support capacity. It has good vibration isolation characteristics can also greatly reduce the damage brought by vibration to the ancient buildings. Xi'an clock tower and other buildings that are extremely sensitive to vibration and need to be protected, which can use GFRP laminated rubber bearing at the connection between the building and the vibration source, this design can play the role of connecting the upper and lower structures to block the vibration energy, which reduces the vibration impact and thus extend the life of the building and better protect the ancient buildings.

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