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STONE CONSERVATION IN CHINA – WITH FOCUSING ON CARBONATE STONE CONSERVATION PRACTICE

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Abstract

The immovable China's cultural stone structures and artistic objects can be broadly divided into three categories: grottoes and inscriptions, stone structures of architectural heritage and ruins or tombs in the underground. First stone conservation investigations were started in 1935. The conservation scientific researches have been cultivated by international cooperations in the 1990's. Following the formation of China ICOMOS in 1993 various conservation principles, technical guidelines with the approval of SACH have been published. From the beginning of 21st century, conservation and restoration intervention practices have been started but with controversial results. From 2008 at least 10 professional laboratories or institutes on stone conservation sciences are very active. Among them the Tongji-ACL and the Institute for Cultural Heritage Conservation Science at the Shanghai University particularly committed. Carbonate stones, such as limestone and dolomite marble are one of most favourable construction and artistic materials. This paper analyzes two practical conservation cases. The first one refers to the rescue intervention to safe Huashan pictographs in Guanxi, the second one describes the development of the conservation concept of a dolomite marble statue in Shanghai. The case studies show how to use traditional lime, like natural hydraulic lime and modernized calcium hydroxide in nano-micro particles to rescue and conserve carbonate stone.

Keywords: cultural stone, carbonate stone, dolomitic marble, natural hydraulic lime, micro lime, conservation

Introduction

China's cultural stone structures and objects are extremely multifaceted. The immovable of them can be broadly divided into three categories Li Hongsong, 2004). The first one includes grottoes and inscriptions, which are built or crafted, carved directly or indirectly into the geological bodies (Fig. 1-A, 1-B). Stone structures of architectural heritage, similar to the stone architecture in Europe, belong to the second one (Fig. 1-C,D,E). The third one refers to ruins or tombs in underground (Fig. 1-F). The grottoes are built predominantly in sedimentary stones, like sandstone, greywacke and limestone. The largest sites of first category are the Dunhauna and Yungan Grottos. The natural stones used as architectural materials vary also from region to region, due to locally available resources,

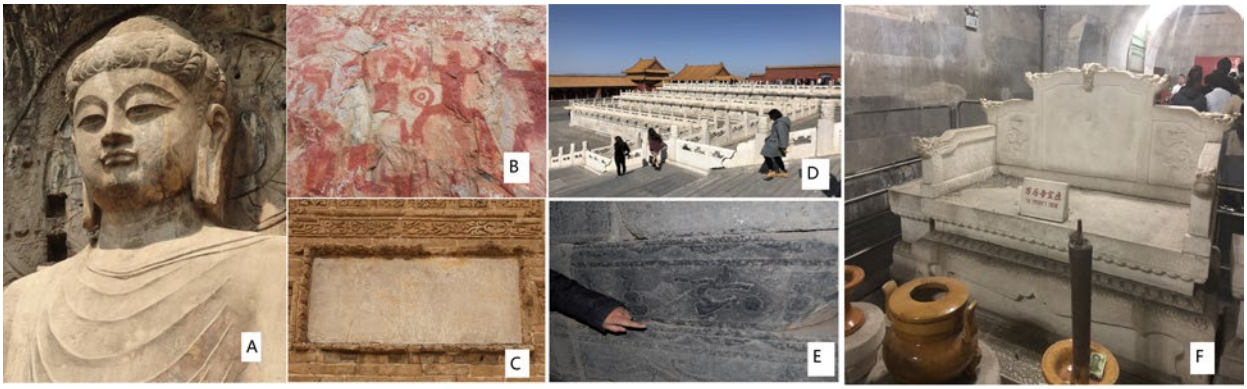

Figure 1: Representative carbonate stone monumments which are listed as UNESCO cultural heritage sites in China (1=Longmen Gottos, buddha stutue caved in dolomitic limestone; B=Huashan pictographs on limestone cliff; C=lime stone inscription in the Great Wall; D=dolomite marble in the Forbidden City, Beijing; E=carviong of football play on the surface of limestone pagoda of Han Dynasty; F=Underground Palace of Ding Mausoleum of Ming Dynasty in Beijing), Source: Dai Shibing.

petrology and logistics. The greatest building of natural stone represents the Great Wall, in which the natural stones are used as foundation, filling, gate and inscription. Natural stones for traditional Chinese architecture are rarely used for entire masonry construction, but widely used for Western styles, or western influenced architecture, i. e. colonial style buildings constructed with a mix of Chinese and Western architecture styles.

Approaches in stone conservation in China – researches and education

The fisrt state owned research institute for stone conservation in China was the former China National Institute of cultural Properties (CNICP, now China Academy for Cultural Heritage), founded in 1935. The most important grottoes were rescued through multiple technique, like grouting and anchoring during in 1960–1970's under leadership of CNICP. The national research base for stone conservation was awarded to the former Xi'an Conservation Centre (now Shan'xi Academy for Cultural Heritage Conservation) in 2007. Following the formation of China ICOMOS in 1993 various conservation principles, technical guidelines (series of WW/T) with the approval of State Administration for Cultural Heritage (SACH) have been published. Those principles and guidelines provide basic integrated and methodological approaches to the conservation and management of stone sites.

The conservation researches have been cultivated 1990's by international cooperation especially with universities and conservation centres from Europe and USA. A few chinese-german cooperation research projects in cultural heritage conservation were sponsored by Federal Government of Germany from 2006 to 2015. However in 2009 a national key pillar research project for stone conservation without international involvements has been launched by SACH. The scopes of the researches are focusing on conservation of sandstone monuments in grottoes, inclusive non-destructive investigation methods, comprehensive exploration technology of water source of grottoes, the stability of gelogical bodies, cleaning of soilings and the conservation and repair work of deteriorated stone. Such comprehensive research projects helped to understand both deterioration mechanisms and technical options under the Chinese administration system to prevent further decay.

From 2008 at least 10 new professional laboratories and institutes on stone conservation sciences have been set up. In 2008 the Architectural Conservation Laboratory of Tongji University (Tongji-ACL) was set up within the faculty of architecture, which focuses on diagnostics and conservation practrices of built stone heritage. In 2017 a new Institute for Cultural Heritage Conservation Science at the Shanghai University was founded under the support of SACH and Shanghai Municial Government to focus on stone-earth conservation sciences.

Figure 2: Workshop of lime for cultural heritage conservation organized by UNESCO World Heritage Research and Training Centre (WHITRAP) in Suzhou in 2018, Source: Dai Shibing & WHITRAP-Suzhou.

In 1989 the conservation subject for Bachelor Degree was firstly offered by the Xibei Universi- in Xi'an. oday, almost 35 universities in China offer study programmes in cultural heritage related fields, inclusive built heritage conservation program. The education in the field of material conservation is however very limited to very few places. As a result, there is a lack of professional conservators in China who are trained to assess materials and to analyze symptoms and causes of deterioration. Recently few courses and workshops cover the issues of stone conservation practices (Fig. 2) to bridge the gap between university education and practical implementation.

Deterioration of stone monuments and practical conservation intervention

All ICCOMOS-ISCS defined deterioration can be found in chinese stone monuments. However, the causes of deterioration are more complicated. The stone materials in grottoes are more affected by quality of the stone materials itself, but also by condensation or geological water in comparison to architectural stone elements or ornaments. The stone in underground are suffered by biological colonization, condensation, delamination caused by fluctuation of temperature and relative humudity .

Obviously accelerating deterioration of stone monuments can be recorded in China since the recent decades (Fig. 3). Figure 3 shows that the inscription was in relatively good condtion after 69 years although they were carved in clay-rich sandstone, but heavely deterioration occured during the last 12 years. The causes will be investigated. They may be related to earthquakes, climate changes, air pollutions and lack of maintenances. Nevertheless this inscription needs to be rescued immediately.

From 2008 a few national conservation projects were launched by SACH. Among them the No. 1 stone conservation project was the conservation of Thousand-Hand Bodhisattva in Dazu. This ten years conservation project was completed with

Figure 3: Inscription of Tongji (同济) carved on 7 July 1938 on sandstone cliff as the Tongji University moved from Shanghai to west because of the Japanese Army invated China. Source: Dai Shibing & Tang Yongjing.

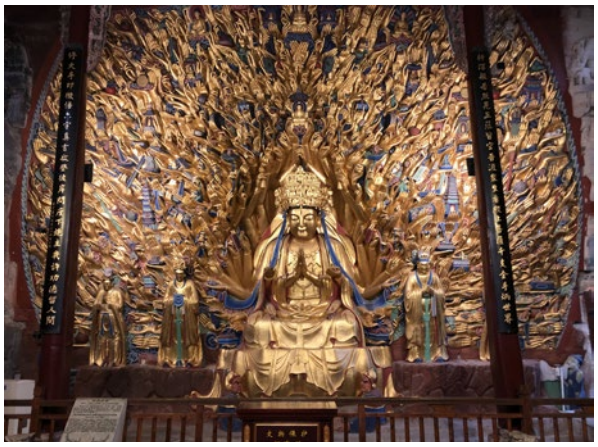

Figure 4: Thousand-hand Bodhisattva in Dazu three years after restoration, Source: Dai Shibing.

contribution of over ten research institutes and universities. However after complishement there were debates on the final appearance (Fig. 4).

Carbonate stone monuments

Carbonate stones are most preferable natural stones for art, recording (inscription) and construction. The widely use of limestone is connected both to geological occurrences and to their mechanical and physico-chemical properties. Llimestone and marble are available all over China except along the southern China coastal regions. Preliminary researches show that all limestones used for construction are very dense, the water absoption is less than 1wt%. Those stones can be well worked, polished and carved due to medium hardness. It is also durable in pre-industrial time.

Some limestone species have surrealistic shapes, patterns and forms with feminine charm. Such limestone is called Taihu Stone used as a prestige decorative stone especially in Chinese gardens (Fig. 5).

However carbonate stone monuments are suffering severe damages especially under the industrial pollution (Fig. 6). Besides cracking, new formation of water soluble salts causes not only material loss of the carbonate stone, but also damages historic adjointing materials. Special conservation concepts need to be developed for carbonate stone conservation.

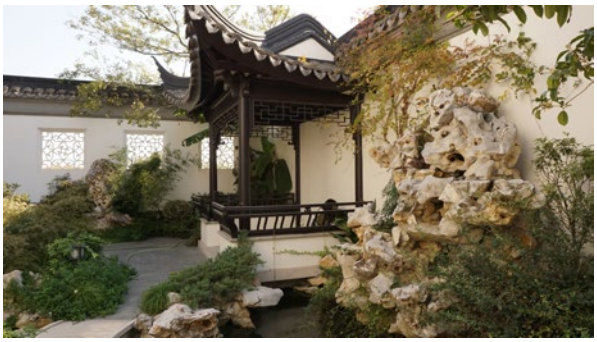

Figure 5: Lime stone is one of the decorated components in Chinese Gardens (hier duplication in new construction). Source: Dai Shibing.

Figure 6: Typical deterioration of dolomitic marble through industrial Na2SO4 dusts. Source: Dai Shibing.

Case study 1 – Surface refitting of *Huashan Pictographs*

The *Huashan Pictographs* is the largest display of rock paintings within the 38 sites of the "Cultural Landscape of Huashan Pictographs along Zuojiang River, Gunaxi Autonomous Region".

The *Pictographs* was painted between Zhou Dynasty and Han Dynasty (5th century B.C. to the 2nd century A.D.) on very dense limestone cliffs.

The *Huashan Pictographs* is the symbol of the ancient Luo Yue culture, the ancestors of the Zhuang ethnic group. They are important cultural relicts of the Zhuang culture and one of the world's largest preserved displays of historic rock art therefore they have high historic and artistic values.

In 1988 the site was listed as "Important Units of Cultural Relics under the National Protection" by the State Council.

Damage symptoms of the *Huashan Pictographs* are typically cracking and loss of paints. Crack width, direction and form are varying. Calcium and clay/

Figure 7: Detachment of limestone and fading of paints of Huashan Pictographs. Source: Dai Shibing.

mud sediments can be found inside the cracks. Loss of paints is not only related to cracking but also to disolving due to condensation. To rescue such cultural heritage, bonding mortars and injection grouts based on natural hydraulic lime (NHL2) have been developed in 2007. NHL-Bonding agent is composed of NHL2 and additives like redisperable acrylic resin (less than 1wt%). It's role is to retach delaminated limestone pieces (middle of Figure 7). To seal cracks, the formulation is to adjust with limestone powder according to the widness of cracks. 15–20wt% of 1–2 mm limestone particles can be added into NHL-bonding agent to seal crack width larger than 5 mm. Injection grout based on NHL2 and superplasticizer is to fill holeness. It has good bonding properties even to clay contaminated cracks. After setting it has high water absorption capacity (over 40wt%) to absorp condensation, which is believed to be one of the main damaging factors for the paint fading of pictographs. Both modified NHL-bonding agent and injection grout have low shrinkage, but similar thermal expansion coefficient in comparison to the corresponding limestone. They show also higher water vapour permeability than that of the limestone. So the condensation within cracks can still evaporate through filled cracks. Because the *Huashan Pictographs* is located in subtropical climate, frost resistance was of no relevance and therefore not tested.

After over 2 years site evaluation on much areas without pictographs and small trial areas with pictographs, this rescue measurement was implemented from 2009 to 2012.

Successful conservation has contributed that Huashan Pictographs was inscribed as Cultural Heritage Site on the World Heritage List in 2016. Other pictographs along the Zuojiang Rivers are being conserved with same concept from 2018.

Case study 2 – conservation and maintenance concept of the Song's dolomite marble statue in Shanghai

Madam Song Qingling was honorary Chairlady of Peoples' Republic of China. The marble statue of Song Qingling is situated in the memorial square of Song Qingling Cemetery in Shanghai, China. The statue is composed of 4 pieces of Hanbaiyu, a kind of valuable artistic natural dolomite marble from Fangshan, Beijing.

After inauguration in 1984, the statue was painted white using various kind of laquer, lastly using polyurethane-modified acrylate paints until 2010. In 2010 it was decided to stripp old paints and to seal marble with clear water repelling sealer with intention to prevent further weathering of the marble from acid rains. This measurement was completed in september 2012. In 2014 it has been found that the water reppelent effect was despeared and many micro cracks (Fig. 8 & 9) occoured on the surface, especially on the head of the statue (Fig. 8). In May 2018 the Tongji-ACL was asked to carry out diagnostic investigation and to work out a conservation and maintenance concept.

Figure 9: Typical macro defects of the dolomite marble of Madam Song's Statue in Shanghai. Source: Dai Shibing.

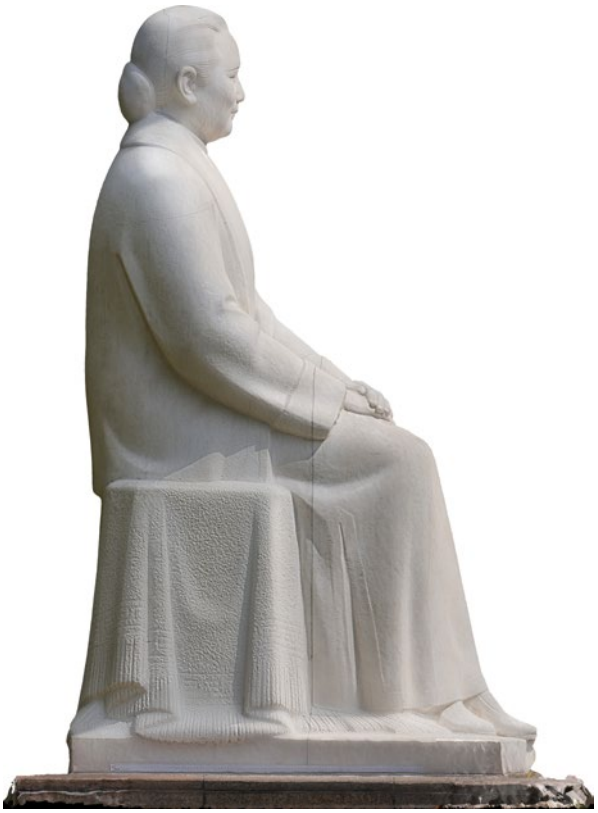

Figure 8: West view of the Madam Song's Statue. Source Tang Zhong.

Under the in-situ microscope, over 30 micro cracks were identified and labeled. The dolomite crystal fabric on the surface is becoming loose with different degrees, even small marble pieces are pelling off. Mineralogically it consists of 92–97 % dolomite ($CaMg(CO_3)_2$), minor quartz and muscovite. This composition is the same as the typical dolomite marble found in Fangshan near Beijing. Epsomite has been idenfied in the marble dusts at the lower part of the statue.

Non-destructive test methods like ultrasonic technology, IR-scanning, water absorption, sanding test with tesa-film etc. were applied to evaluate the conditions.

Surface consolidation tests with micro lime (dispersed $Ca(OH)_2$ with partical size of 0.2–3 µm in ethanol) and low concentrated ethyl silicate show satifying results. The pull-off strength of micro lime on fresh cracked dolimitic marble can rearch 0.1–0.3 Mpa in 14 days. So the micro lime can work as a new binder to seal cracks.

Based on evaluation of all test results and international positive experiences with micro-nano lime, a conservation concept inclusive a monitoring program especially to control cracking has been worked out. This concept has been approved by authorites and is being implemented from December 2019.

Conclusion and discussion

China's cultural stone structures and objects are extremely multifaceted. Carbonate stones (lime stone, marble and dolomitic marble) are mostly used as stones for religious grottoes, building and construction, inscriptions and so on. They are in danger not only due to special geological environments, like grottoes and caves, underground tombs and ruins, but also due to strong air pollution. Special care is needed to conserve or restore destroyed monuments, at the same time sustainable maintennace for carbonate stones shall be planned. Two case studies show that using traditional materials, like natural hydraulic lime, or calcium hydroxide dispersed in alcohol, with help of modern chemistry, may provide solutions for conservation. However more researches are needed. First of all the deterioration mechanisms have to be investigated under modern air pollution and it has to be find out how this deterioration affects durability of the stone monument itself, also refering adjointing historic materials and conservation effectiveness. Due to the vast size of the country and the extreme differences in topography, stone structures exposed to very diverse climatic conditions and the degradation of such structures varies significantly. The second is the research on the sustainable conservation and maintenance concept. The third one is the monitoring. Some of the carbonate stone monuments which are exposed directly to weather in the region Nanjing, southen China, have been conserved with synthetic resin with satisfying results. All those results have to be evaluated.

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