VERNACULAR ELEMENTS IN RURAL CULTURAL LANDSCAPES DIFFERENT FROM URBAN CULTURAL LANDSCAPES AS A TOOL FOR SUSTAINABILITY IN ELMALI CASE

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Keywords: Vernacular Architecture, Rural Cultural Landscape

Abstract.

Introduction:
Man-made elements have a big significance in cultural landscapes, which are considered as joint products of humans and the nature. The most typical products of the interaction be-tween architecture and landscape appear with vernacular architectural elements in rural cultural landscapes. Here, the vernacular architectural elements define the structures built with the natural materials and traditional building techniques in the region of their location. While the pressure of a cultural change, and eventually different functional needs and population growth usually influence the historic fabric in the urban areas, life flows and changes more slowly in rural areas. People from rural areas are more attached to their traditions, lifestyles and land. As often observed in the Anatolian geography, the almost deep-rooted and steady lifestyle enables using the same vernacular architecture.

Developments:
It is important to protect the vernacular architectural elements not only as a way of structure, but also the way of their tradition and identity. Because the vernacular architectural elements reflect the landscaping and traditional lifestyles of the region they present and reflect the cultural, historical and natural characteristics of the region.

Remarks and Conclusion:
In this study, alternatives will be discussed enabling to view the vernacular architectural elements and the sustainable use of the locally specific characteristics with regard to forms and functions in case of Elmalı District, Antalya. Elmalı District has been selected as study area due to its diversity of local architecture reflecting regional history with rich natural structures, traditional land use patterns and local architectural elements. Lifestyles of local inhabitants in the district did not change much and their means of living and traditions typically continue. We hope that study results would contribute to understanding how the vernacular architectural elements are influenced by the nature of the district in terms of their location, form and function and how protection of rural landscapes and use of vernacular elements can be more sustainable.

1 INTRODUCTION

Matters such as preservation of historical structures within urban cultural landscapes within the framework of an official status, how to develop within urban historical patterns have always been the matter in question. Successful examples have been given on this matter. However, vernacular architecture available in rural cultural landscapes mostly consists of structures which don't have an official preservation status. Some of these structures are still in use; some of them are abandoned and some other failed to stand the test of time or are demolished to be replaced by the new ones. While cities are constantly in motion and a state of flux, rural vernacular architecture structures are usually forgotten and waiting in a constant process.

This study handles vernacular architectural elements unique to a region in rural landscapes mostly differentiated from urban landscapes by their local characteristics, in terms of Antalya-Elmalı example and sustainability. Study results are expected to understand how local architectural examples are influenced of natural building factors as well as to make contributions to matters of preservation of rural landscapes and sustainable usage.

2 MATERIAL AND METHOD

Antalya city, Elmalı county has been selected as the study area due to availability of rural cultural landscape areas whose sustainability still continues and which are not changed too much because of transportation issues. Elmalı is located in the Mediterranean Region, west part of Taurus Mountains and Antalya Gulf, in the middle part Teke Peninsula, between east longitudes 29° 50'- 30° 11' and North latitudes 36° 31'- 36° 54'. The county being on the trade route connecting Anatolia to the Mediterranean Sea, has been an important settlement center throughout the history due to affluent water resources and fertile soil (Figure 1).

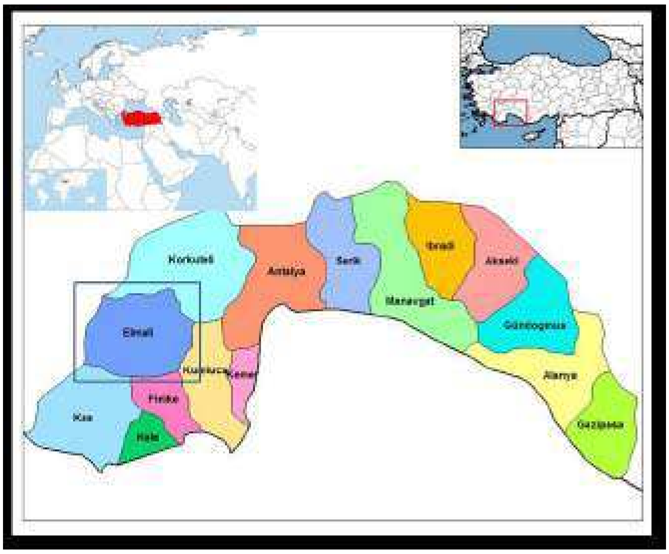

Figure 1: General Location of the Research Area

In this study, urban and rural settlements are briefly analysed under Elmalı county example as well as the matter of local architectural structures' preservation in rural areas will be emphasized.

Generally, free settlements developed spontaneously and ordered settlements are observed in rural cultural landscapes having an environmental view created as the result of humans' activities out of cities [1]. Except residential buildings, a mosque located at the village center, school buildings which are generally empty, local storage buildings in villages where fruit growing is developed, small scale animal housings, granaries which are available in almost each house's garden, mills, molasses production places in villages where viticulture is developed and beehives are seen among local architectural examples built usually with stone, adobe and wood in Elmalı's rural cultural landscapes.

3 RURAL CULTURAL LANDSCAPES LOCAL ARCHITECTURAL ELEMENTS

Contrary to urban landscapes establishing Elmalı's urban settlement, rural cultural landscapes covering villages provides significant differences. Farmlands in villages consist of greenhouses, vineyards, fruit gardens, lands as well as artificial and natural fences separating them at intervals. Besides, some villages have forest and maquis lands at mountain slopes as well as open fields such as grasslands, grazing lands, village square or threshing fields at bottom lands. Gar-dens of village houses are generally surrounded by artificial or natural fences; includes fruit trees and occasionally, small vegetable gardens.

Rural cultural landscapes as well as urban cultural landscapes may differ from each other as is known.

While urban cultural landscapes show dense settlement order like attached buildings, rural cultural landscapes show free settlement order consisting of separate buildings.

While function of urban places in urban areas may undergo constant changes, function of stable rural places in rural areas doesn't change for many years.

Variety of people's source of income is limited in rural areas; however, in urban areas, there are variable and various groups of source of income. Housing requirements appears accordingly.

People of rural areas encounter compliance issues when they leave their house where they live adjacent to their animals, agricultural soil or production workshops and move to urban places such as reinforced concrete buildings and their lives become more difficult.

4 ARCHITECTURAL ELEMENTS UNIQUE TO THE REGION AS A TOOL FOR SUSTAINABILITY

This study examines residential buildings, granaries, molasses production places and bee hives available in Elmalı County (Figure 2).

Materials used in residential buildings of Elmalı's rural areas are stone, wood and adobe. Most of the time, structures are built by applying half-timbering technique in which lower floors are made of stone and higher floors of adobe. Almost all structures are still in use. Some repairing in wet areas such as bathrooms and toilets or additions to buildings was made. It is possible to see some buildings built by reinforced concrete technique among local architecture. These buildings almost don't exist in some villages however, are quite numerous in some villages.

Granaries are unique and local cultural landscape elements built and used as of 2500 years ago to present in Lykia Region [2]. Built by wood masonry system with rubble stone used for foundation and cedar wood. Building whose sustainability may be ensured in the easiest way since its construction and use still continue.

Molasses production places are also still in use in Elmalı county. In rural cultural landscape areas where viniculture is highly common, people produce molasses in these places. These are buildings whose preservation and sustainability may be ensured since they are still in use, and enables sustainability in terms of human use and life.

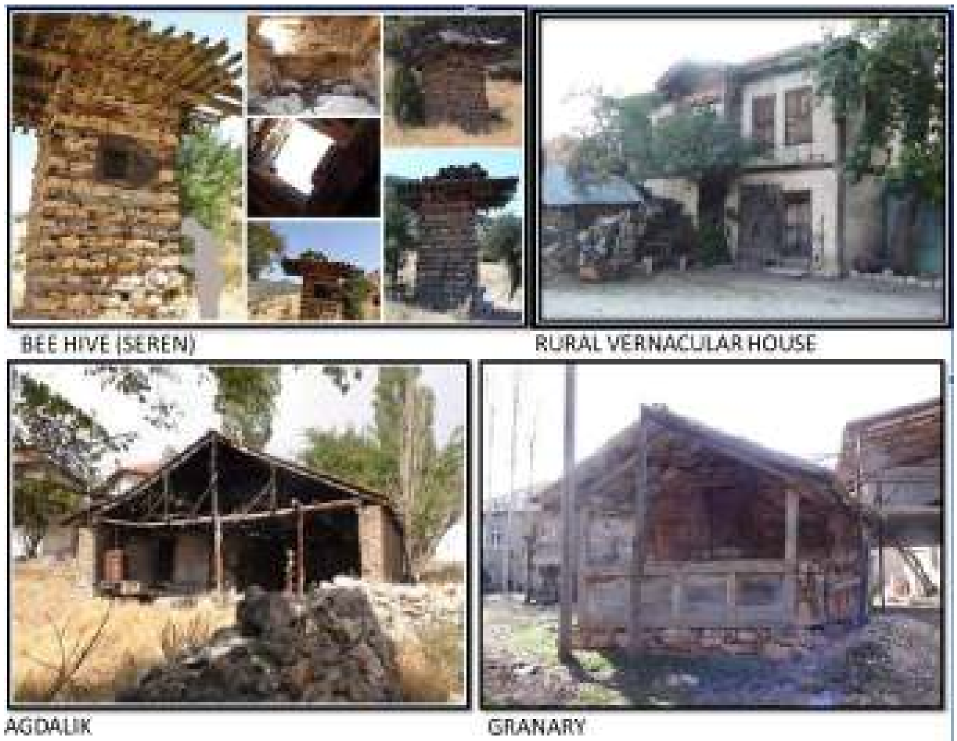

Figure 2: Examples of residential buildings, granaries, bee hives and granaries in Elmalı county

Bee hives locally called 'seren' are made of stone and wooden materials among lands and grazing lands, consisting of hollowed cedar wood blocks called 'black hive' which are black and round placed on a wooden platform on a high rectangular parallelepiped built by putting up as a dense hacking dry wall. New systems are now used for apiculture in Elmalı. However, bee hives may be preserved and serve to rural tourism.

5 DISCUSSION AND CONCLUSIONS

Landscape deemed as a significant indication of life quality, rural and urban areas are considered as an important component of life quality for everybody from everywhere with their ordinary but also extraordinarily beautiful areas [3,4]. While Agnoletti [5] emphasizing necessity to preserve cultural landscapes.

Architectural elements constituting significant part of cultural landscapes don't describe mostly quality of cultural landscape. Kavas [6] stating that life style and landscape as well as local architecture in rural settlements are an inseparable whole, defended a total aesthetic understanding with available landscape and life.

Preservation and sustainable use of local architecture have a great importance as a whole together with its form, construction technique and material which reflects cultural values such as life style, landscape use of local people and which is an inseparable part of cultural structure.

All local architectural elements examined in Elmalı, local materials such as adobe, wood, stone, traditional construction methods such as wooden interlocking construction technique have unique values. On the other hand, these local architectural elements are elements of rural cultural landscapes which still exist. For example, granaries are almost fully used although there is a transition from cereal production to fruit- vegetable growing and if needed, may be rebuilt and show that sustainability may be ensured by same design principles and materials of local architecture.

Vural vd [7] and Günçe [8] present building recommendations made according to local design principles but by using contemporary materials and construction techniques in their studies. However, original materials used in these buildings should be preserved in terms of integrity of landscape and available architecture. Considering examples of Elmalı's local architectural elements in terms of preservation and sustainable use of architectural elements, almost all granaries are still in use and it is possible to build them by local people in conformity with the original. Molasses production places are still in use and have special functions and built for villagers' common use.

Upon examination of status of local architecture in the legal legislations, National Rural Development Strategy Document entered in force by being published in Turkey at the Official Gazette on 4.2.2006 with issue no 26070 comes to the forefront. There is also the communique published by Ministry of Public Works and Settlement in year 2007. Furthermore, pursuant to paragraph 3 of article 57 of the Building Bylaws for Unplanned Areas, it has been decreed that projects may be provided by governorates in conformity with traditional, cultural and architectural characteristics of the region for buildings to be constructed in rural settlements when requested. In August 2011, it has been stipulated in article 27 of the Building Law numbered 3194 amended by the Statutory Decree on Organization and Duties of Ministry of Environment and Urbanism that "except municipality and neighboring areas, houses and non-domestic spaces within villages' rural settlements and their surroundings must be in compliance with local pattern and architectural characteristics, science, art and health rules". Legal regulations also support preservation of local architecture as a whole with cultural landscape. However, difficulties in practice have been discussed.

One of the ways to keep rural economy alive is rural tourism basing on natural and especially cultural values. Elmalı Region has an important rural tourism potential with its climate conditions and especially traditional life and architectural elements as an alternative to coastal tourism in Antalya.

Relationship and interaction of local architecture and cultural landscape come to the forefront in areas where natural and cultural structure constituting cultural values such as life style and landscape use are an inseparable whole and especially which have cultural landscape quality.

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THE BUDDHIST THREE JEWEL MONASTERIES IN KOREA
THE MEANING AND CHARACTERISTICS OF THE THREE JEWEL MONASTERIES AND THEIR CONSERVATION AND RESTORATION PRACTICES

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Keywords: Conservation, Restoration, Intervention, Heritage Classification, Ocean Seal Diagram, Three Jewel Monasteries in the Jogye Order of Korean Buddhism (JOKB)

Abstract.

Introduction:
The Buddha; the Dharma; the Sangha - the Three Jewels in Buddhism are the three things that the Buddhists take refuge in, and look to for guidance. In Korea Tongdo-sa represents the Buddha; Haein-sa represents the Dharma, or the Buddhist Teachings; and Songgwang-sa represents the Sangha, or the Buddhist community. In each of these Three Jewel Monasteries, the most important building is the one that signifies and embodies its particular jewel. And the architecture of the Three Jewel Monasteries is interwoven with the Venerable Uisang's Ocean Seal of Hwa-eom Buddhist Philosophy.

Developments:
The recognised interpretation of the arrangement of the buildings is based only on the conventional description of the monastery complexes. However, building arrangements and the hierarchies in these monasteries show the complete and perfect mutual interpenetration of phenomena and phenomena based on one stanza of Ocean Seal Diagram: in one is all and in many is one; one is identical to all and many is identical to one.

Remarks and Conclusion:
A constructive step for us all to take would be to consider the idea of initiation of principles and guidelines for the conservation and restoration of three Jewel Monasteries, the idea of good design intervention as a conservation strategy and the idea of proper classification of the heritage category based on its classification system in Korea. A well-funded research with advanced method should be conducted to achieve the documentation of the Buddhist three Jewel monasteries conservation and to ensure management under ideal circumstances with guidance of the new design attached to the three jewel monasteries:

1 INTRODUCTION

The Jogye Order of Korean Buddhism (JOKB) is the representative order of traditional Korean Buddhism that date back 1,200 years to Unified Silla or Later Silla (668-935 CE [1]) National Master *Doui*. He brought *Seon* (Chin. *Chan*, Jap. *Zen*) and the practice taught by the Sixth Patriarch, Hui-Neung (638-713 CE) from China ca. 820 CE.

The JOKB takes the teachings of the Buddha Sakyamuni as its basis and its principles are transmission of Seon, realisation of Buddha nature, and propagation. The Order relies on the Diamond Sutra and Inherited Buddhist Literature as a guiding text and through Sutra study, chanting and devotional practices are integrated into the program, the most important and widely known practice is Hwadu meditation. The Diamond Sutra or Vajira sutra is a short and well-known Mahayana Sutra from the "Perfection of Wisdom" genre, and emphasizes the practice of non-abiding and non-attachment.

1.1 The Three Jewels and the *Tripitaka*

The Three Jewels in Buddhism are the three things that Buddhists take refuge in, and look to for guidance, in the process known as “taking refuge”. They are Buddha, the Enlightened One; Dharma, the Buddha’s Teachings; and Sangha, the Buddhist Community. They are also called the Three Treasures, the Three Refuges, or the Triple Gem. In Korea *Tongdo-sa* represents the Buddha; *Haein-sa* represents the Dharma, or the Buddhist Teachings; and *Songgwang-sa* represents the Sangha, or the Buddhist community. In each of these Three Jewel Monasteries, the most important building is the one that signifies and embodies its particular jewel. Thus, the main hall in Tongdo-sa opens out onto a Stupa which the faithful claim contains relics of the Buddha; Haein-sa has two large buildings holding the *Tripitaka Koreana*; and Songgwang-sa has several prominent buildings dedicated to its monastic community including the numerous *Seon* masters the temple has produced.

The Tripitaka is traditional term used by Buddhists to describe their various canonical texts, divided into three parts: the *Sutra-pitaka*, a collection of scriptures recording the teachings of the Buddha; the *Vinaya-pitaka*, containing the rules governing the monastic community; and the *Abhidharma-pitaka*, a collection of Buddhist philosophical writings.

1.2 *Chongnim*, Comprehensive Monastic Practicing Compound

Chongnim, comprehensive monastic practicing compound comes from Dannim, which in Sanskrit means “vindhyavana,” and compares to a thick forest, the gathering of many monks and ordinary people for practicing. The head of a *Chongnim* is called a *Bangjang*, *Seon* master. There are currently five *Chongnims* in the Jogye Order of Korean Buddhism: Tongdosa, Yoengchuk Chongnim since 1972; Haeinsa, Haein Chongim since 1967; Songgwangsa, Jogye Chongnim since 1969; Sudeoksa, and Baekyangsa. To qualify as a *Chongnim* in Korea, a temple is required to have *Gangwon*, Sutra School: *Yulwon*, Precept school or Vinaya School: *Seonwon*, Meditation school: and *Yombulwon*, Chanting school. However, not every temple has all of these schools and centers. After completing basic education and receiving *Samigye* or commandments for Buddhist acolytes, all Buddhist priests enroll in a four-year Buddhist course at a lecture hall, a Seon Meditation hall, or a disciplinary hall. After completing this four-year course, they qualify to receive the *Bigugye* commandments.

1.3 *Uisang*'s Ocean Seal of *Hwaeom* Buddhism

Master Ui-sang (625-702) was one of the eminent early Silla scholar-monks and a Buddhist philosopher. The Three Jewel Monasteries are all related to the Uisang's Ocean Seal Diagram of *Hwaeom* Buddhist Philosophy. Its architecture is interwoven with this philosophy.

Refer to 'Uisang; Encyclopedia of Religion,' Diagram of the Dharmadhatu, the dimensions of the world, of the One Vehicle of Hwaeom is a short poem of 210 logographs in a total of 30 stanzas. The poem is arranged in a wavelike form, the "Ocean Seal Diagram", which symbolizes the Hwaeom teaching of the "six marks": universality and particularity, identity and difference, and integration and disintegration. The entire structure of the diagram represents the marks of universality, identity, and integration, while its curves designate the particularity, difference, and disintegration marks. The Diagram is woven into one continuous line to show that all phenomena are interconnected and unified in the Dharma-nature; the fact that this line ends at the same place where it began illustrates the cardinal Hwaeom doctrine of interpenetration. The diagram is divided into four equal blocks, indicating that the dharma-nature is perfected through such salutary practices as the four means of conversion: giving, kind words, helpfulness, and cooperation. Finally, the 54 corners found along the meanderings of the line of verse indicate the 54 teachers visited by the pilgrim Sudhana, the child of the wealth, in his quest for knowledge as narrated in the Gandavyūna chapter of the Avatamsaka Sutra. Hence, the diagram serves as a comprehensive summary of all the teachings found in the sixty-fascicle recension of the Avatamsaka Sutra.

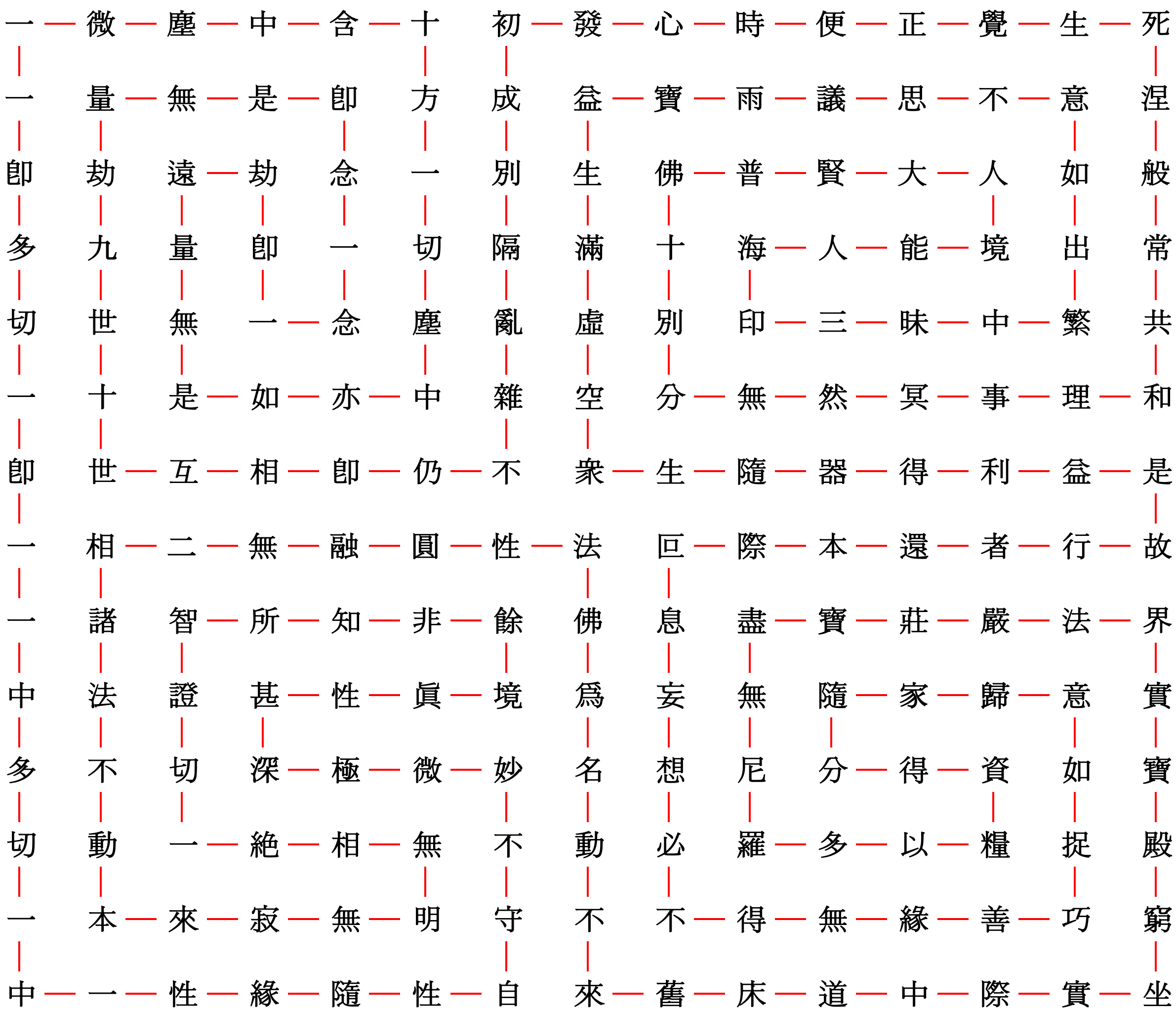

Figure 1: *Hwa-eom ilseung beobgye do* (An Explanatory Diagram on the Garland World System or Diagram of the Dharmadhatu of the One Vehicle of Hwa-eom, written in 668)

2 DEVELOPMENT: THE BUDDHIST THREE JEWEL MONASTERIES IN THE JOGYE ORDER OF KOREAN BUDDHISM

2.1 The Buddha Jewel Monastery, *Tongdo-sa*

2.1.1 The meaning and value of Tongdo-sa

Tongdo-sa means "Pass into Enlightenment' Monastery." The name has three different interpretations: 1) the shape of the Mountain Youngchui is very similar to the "Vulture Peak," the site where the Lotus Sutra was expounded; 2) people who become monk should pass into the Precepts Platform; 3) and after the practice, should save all beings. It is the first of Three Jewels Temples of Korea, representing the Buddha and is traditionally a Seon Practicing Temple. It is the largest temple in Korea as it has the most number of buildings. It was once the centre of Korean Buddhism.

The value of this Temple lies in the enshrined relics of the Buddha and the Monastic Robe which Master Jajang brought on his return from T'ang Dynasty China.

2.1.2 Brief history and founder of Tongdo-sa

It is said that Tongdo-sa was built in 646 C.E. during the reign of Queen Seondeok (632-647 C.E.) in Silla Kingdom by Vinaya Master Jajang (608-686) who brought relics of the Buddha from China. It was rebuilt in 7^{th} century C.E. and most of the buildings constructed during the Joseon Dynasty.

There is a famous legend of Master Jajang, the founder of this Monastery and the builder of Vajira or Diamond [2] Precept Platform: Jajang was a son of Murim Kim. He belonged to an aristocratic family. Born after he was named Sonjongnang which means "a child, born with good karma" as his birthday coincided with the Buddha's Birthday. He could have advanced well in the court, but he chose to be a monk. Master Jajang belonged to Vinaya School. The King Jinpyong, appreciating his talents, cajoled him to accept a court position, with no avail. The King declares beheading of him. But the dauntless monk replied, "I prefer to live one day keeping Vinaya, the rules, than to live a hundred years without keeping Vinaya." Profoundly moves, the King allowed Jajang to remain a monk for life. Actually the foundation of this Temple was rooted in the monk's assiduous practice. He was a great Vinaya Master rather than Sutra or Abhidharma Master. Vinaya is the monastic Discipline and the collection of the rules; Sutra is the Discourses or teachings of the Buddha; Abhidharma is the Analysis of mind and matter, higher philosophy

2.1.3 Architectural Heritage at Tongdo-sa

Tongdo-sa is in the Mt. Chuiru or Youngchui at Hanbuk (north of stream), Yangsan-si, Gyeongsangnam-do. As the name shows, there is a mountain in the north and stream in the south. It is an auspicious location according to geomancy. The layout of buildings is extraordinary, compared to other temples in Silla Dynasty. At that time, a main hall and a Stupa are one after another on the south-north axis in the typical layout of Temple. More than 65 buildings of this temple, standing from the One Pillar Gate to the Main Buddha Hall, give the impression of linear settlement or dwelling compound.

To illustrate the importance at Tongdo-sa, the Diamond Precepts Platform and the Main Buddha Hall is in the innermost important and unusual area of the compound. Behind the Main Hall is the Diamond Precepts Platform. On the Platform is the bell-shaped Stone Stupa surrounded by a stone barrier. The gate is finely decorated with dragons, clouds and two protector guardians. There are protective deities on the four corners of the platform. The ball-shaped Stupa is decorated with lotus patterns, lotus blossoms, lotus petals, the Four Virtues and gods on the base and upper parts. In front of the Stupa lies the lovely Nine Dragons Pond. Originally very large, the pond was home to nine dragons. This Stupa is believed to enshrine the relics brought from China by Master Jajang and it is the focal point of the temple.

The Main Buddha Hall is unique in that it has no Buddha Image, only a window looking out to Stupa, which contains the relics of the Buddha. Since it represents the Buddha, there is no need for an Image of Buddha. The Main Buddha Hall was reconstructed in 1601 in the reign of King Seonjo (1567-1608) of Joseon Dynasty. In 1997 the Main Hall and the Diamond Precept Platform area was designated as National Treasure No. 290, which is upgrades from Treasure No. 144. Diamond Precepts Platform, where the relics of Buddha are enshrined, is presumably constructed in the middle of 7th century C.E. It was restored several times and existing Platform of 17th century. It has been altered from the original one, but remains the largest and the most beautiful one in Korea.

When it was founded, there were only few buildings: the Diamond Precept Platform and the Main Buddha Hall, the Great Hall of Buddha's Light (Vairocana Hall), the Lotus Sutra Hall, and the Hermitage of Master Jajang etc. The Main Buddha Hall faces east on the main linear axis and south on the Precept Platform-Main Hall axis, so it needs two faces and two different exterior spaces.

2.1.4 Important monastic assets at Tongdo-sa

The enshrined relics of the Buddha and the Monastic Robe which Master Jajang brought with him are the most important treasures here. There is a stone Pagoda in front of Yongwhajeon Hall (Treasure No.471). It looks rather a stone Alms Bowl than a Pagoda. There is an 1896′s Rock-cut Buddha-Triads in the Hermitage Jajang-am.

There are early 14th Century's Avatsamka Sutra Part 46 (Treasure No. 757) and the 1386's new and unique wood-cut Musaeggegyoung Sutra (Treasure No. 738). "Musaegge" is the Formless world whose inhabitants have no physical form. There is a Buddhist ritual artifact of Middle of the Goryeo Dyansty (918-1392 C.E.), Bronze incense burner with design in inlaid silver (Treasure No. 334).

2.2 The Dharma Jewel Monastery, *Haein-sa*

2.2.1 The meaning and value of Haein-sa

Haein, the "Ocean Seal" means "Reflection on a calm sea." It is the description of a state of meditation Samadhi taken from the Avatamsaka Sutra (Hwa-eom or Flower Garland Sutra) which compares the wisdom of Buddha to a calm sea. When the sea, that is the human mind, is freed from the wild storms of worldly desires and follies, it will finally attain a mirror-like peacefulness where the true image of all existence is clearly reflected. In the Sutra, the Ocean Seal Samadhi is a stage in which an enlightened one sees everything as it is: a world in which all dualities cease. Such a world has a surface like that of a calm sea.

Haein-sa is the second of Three Jewel Monasteries of Korea and the full monastic practicing temple, representing Dharma, the teachings of Buddha. It is the Foundation Temple of Hwaeom School of Korean Buddhism and houses the *Tripitaka Koreana*.

2.2.2 Brief history and the founder of Haein-sa

Haeinsa is nestled within the hills of Mt. Gaya in Gyeonsangnam-do Province. At first a hermitage, Haein-sa was built by two monks Su-neung and I-jeong on their return from China in 802. Legend says that two monks healed the Queen of King Aejang (r. 800-809) of Silla, when she suffered from a tumor. They tied one end of a piece of string to the tumor, the other to a tree, and chanted special verses. Miraculously, as the tumor withered, the tree died. In gratitude of the Buddha's mercy, the king ordered the construction of a temple. Later the temple was greatly enlarged. Haien-sa burned down in 1817 and the main hall was rebuilt in 1818. Another renovation in 1964 uncovered a royal robe of King Gwanghaegun, who launched the 1622 renovation, and an inscription on a main ridge beam.

The Depositories for the *Tripitaka Koreana* woodblocks were added to UNESCO World Heritage List in 1995. The UNESCO committee noted that the buildings housing the Tripitaka Koreana are unique because no other historical structure was specifically dedicated to the conservation of artifacts and the techniques used were particularly ingenious.

2.2.3 Architectural Heritage at Haein-sa

The wooden storage halls, known as the Janggyeong Panjeon complex (National Treasure No.52), are the depository for the *Tripitaka Koreana* woodblocks at Haein-sa Temple. Remarkably, the halls were untouched during the Japanese invasions of the Seven-Year War in the late 16^{th} century and the halls were spared from the fire that burnt most of the temple complex down in 1818. The storage halls have survived seven serious temple fires and even a near bombing during the Korean War when a pilot disobeyed orders to drop bombs because he remembered that the temple, suspected as a communist guerilla hideout, held a precious treasure.

Janggyeong Panjeon complex is the oldest part of the temple and houses the 81,258 wooden printing blocks from the *Tripitaka*. Although when the hall which houses the *Tripitaka Koreana* was first built is uncertain, it is believed that King Sejo of Joseon expanded and renovated the hall in 1457. The storage complex, made up of four halls, is arranged in a rectangle and its architectural detail is very simple because of its use as a storage facility. The northern hall is called Beopbojeon (Hall of Dharma) and the southern hall is called Sudarajang (Hall of Sutras). These two halls are 60.44 meters long, 8.73 meters width, and 7.8 meters high. It is a building of 15 *kan* (bays) in the purlin direction (*dori-kan*) by 2 *kan* in the transverse beam direction *(bo-kan)*. [3] Additionally, there are two small library halls in the east and west.

The main Buddha hall at Haeinsa used to be called “Birojeon” (the Hall of Vairocana). It was renamed “Daejeokgwangjeon (The Hall of Great Calm and Brilliance)” and was reconstructed at the end of 15th century. After a series of fires, the present building was reconstructed in the early 19th century on the foundation of the one built in 802. It was extensively repaired in 1971. It is a building of 5 *kan* (bays) in the purlin direction (*dori-kan*) by 4 *kan* in the transverse beam direction *(bo-kan)* on top of the stone platform, and of a multi-cluster bracket system with a hipped-and-gabled roof. There are seven Buddha images in the hall.

2.2.4 Important Buddhist Assets at Haein-sa

Tripitaka Koreana (National Treasure No. 32) was originally carved in the 11th century in a temple on Kanghwa Island, west of today’s Incheon. It was believed that the possession of these wood-blocks would protect the country against invasion. Ironically the blocks themselves were later burnt by invaders, the Mongols. In the 13th century a new set was undertaken at the orders of King Gojong (r. 1213-1259) of Goryeo and these were transported from Ganghwa Island on the heads of nuns to Haein-sa for safekeeping.

The manufacturing process usually accepted is: the wood used is white birch; for three years it is submerged in sea-water; for three years it is boiled in seawater; for three years it is dried in the shade. It took about 16 years to carve the 52,330,152 characters on the 81,258 blocks. Because of the uniformity of the carving it is believed that the work was done by one person, although it was the work of many. When printed, there are about 6,791 large volumes.

2.3 The Sangha Jewel Monastery, *Songgwang-sa*

2.3.1 The meaning and value of Songgwang-sa

Songgwang-sa means "Spreading Pine Temple." It was established on Mt. Jogye-san by Master Jinul (1158-1210 C.E.). The words "Songgwang-sa" and "meditation" are synonymous. The name was from the site that Ven. Jinul's meditation teachings began to spread like a pine. Songgwang-sa is the third of Three Jewels Monasteries of Korea, representing the Sangha or community of followers of Buddha. Ven. Jinul was posthumously given the title of National Master Buril Bojo. Venerable Jinul systematized a uniquely Korean style of Seon practice that continues, and 15 of his successors at Songgwang-sa were given the title of National Master during the remaining centuries of Goryeo. The Master's Portrait Hall was built and the temple came to represent the Sangha. The temple also houses Korea's first International Seon Centre, founded by the late Seon Master Venerable Gusan, who attracted a strong international following in the 1970s and early 1980s.

A three-month session of intensive meditation retreat (*An-geo*) is the most meaningful in Songgwang-sa than any other temples in Korea.

2.3.2 Brief history and founder of Songgwang-sa

Records indicate that Ven. Hyerin first built a small temple called Gilsangsa during late Silla Period (57B.C.E.-935C.E.). The name of the temple was changed to Suseonsa, the name that is still used today for the meditation hall. This temple eventually became Songgwangsa. The name of the mountain was changed to Mt. Jogye [4], after the mountain where the sixth patriarch of Seon (chn. *Chan*, jap. *Zen*), Hui Neung had lived in China. This name change shows a kind of respect for the special tradition of Seon. Ven. Jinul was the first Korean master to adopt the Hwadu approach [5]. Today it remains the main method used in meditation halls throughout the country.

In 1190, Master Jinul formed a “Concentration (*samadhi*) and Wisdom (*prajna*) Community” at Geojo-sa in North Gyeongsang province for practicing Buddhism together. After seven years he had to expand to accommodate his growing community. Searching for a suitable meditation site for his growing community of meditation followers of Buddha, he carved a crane out of a block of wood, which he then released. The crane flew away and finally landed in the place where Songgwang-sa Temple is today. "The site was outstanding, the land was very fertile, the springs were sweet, and the forests were abundant. It could truly be called a place appropriate for cultivation of the mind, nourishment of the nature, the gathering of an assembly, and the making of merit."

Ven. Jinul's Buddhist philosophy created an ancient Buddhist debate that continues still. He believed that enlightenment could be quite easily reached but that practice must continue afterwards in order to get rid of the habit energies. This is called the Sudden Awakening and Gradual Cultivation as opposed to Sudden Awakening and Sudden Cultivation, wherein after a struggle to reach the difficult stage of enlightenment, cultivation is no longer necessary.

2.3.3 Architectural Heritage at Songgwang-sa

To illustrate the importance of meditation at Songgwang-sa, several of the mediation-related buildings, including the quarters of the Seon masters, meditation halls, and a portrait hall are all located behind and even higher than the Main Buddha Hall, and elevated some fifty feet up on the hillside, something that cannot be found at any other temple. The Meditation Hall and the Hall of 16 National Masters are the places which best show the characteristics of the Sangha Jewel Monastery tradition. This emphasizes the importance of the meditation and practicing, making it different from other temples. The meditation halls, Sangsadang (current Sam-il-am) and Hasadang (Treasure No. 263) are built on higher location at the rear side of the Main Hall [6].

A symbolic hall, enshrining 16 portraits of National Masters, is a wooden structure built in 1420 (Treasure No.56). This hall became a symbol of Songgwang-sa since it was not damaged at all even through so many disasters. However, this area is sealed off from the rest of the monastery and is only accessible to those monks undergoing training in the meditation hall.

West of the main hall is the Sangha Jewel Hall. It was moved from the present main hall site. Before the current main Hall was built, this Sangha Jewel Hall used as the Main Hall. It enshrines the image of Sakyamuni Buddha along with 10 major disciples, 16 saints, and 1250 Bhikkus by reproducing the Assembly at Vulture Peak [7], Yeongsanhoesang. It symbolizes Songwangsa as the Sangha-Jewel Monastery, and The Ox-Herding Paintings [8] are drawn on the left and right walls. Especially, the fifth painting, Ox-Herding, means cultivation of mind and has a close relationship with *Mokwoogapoong*, which represent practicing tradition of this monastery.

East of the Main Hall is the Judgment Hall, Ksitigarba and the Ten Judges of Hell are enshrined here. A lecture hall and a Precepts hall are located a little apart from this main site. Yaksa-jeon, the Medicine Buddha Hall (Treasure No. 302) is housing the Medicine Buddha, the Universal Healer. It is the smallest Buddha Hall in this monastery compound. It is one-*kan* building.

2.3.4 Important Buddhist assets at Songgwang-sa

The wooden Buddha-triad casket (National Treasure No. 42) and the Illustrations of the Avatsamsaka Sutra (National Treasure No. 314) are the most important tangible legacy of Songgwang-sa.

3. REMARKS AND CONCLUSIONS: THE CONSERVATION, RESTORATION AND MANAGEMENT OF THE THREE JEWEL MONASTERIES IN THE JOGYE ORDER OF KOREAN BUDDHISM

The recognised interpretation of the arrangement of the buildings is based only on the conventional description of the monastery complexes. However, building arrangements and the hierarchies in these monasteries show the complete and perfect mutual interpenetration of phenomena and phenomena based on one stanza of Ocean Seal Diagram: in one is all and in many is one; one is identical to all and many is identical to one.

3.1 Interpretation of the arrangement of the buildings

3.1.1 Tongdo-sa

Generally known description of the temple complex is three levels or three areas theory. The compound is consisted three Areas: from the east to the west, the Lower Area, the Middle Area, and the Upper Area. These Areas divided by the Mountain Gates and Pagoda. One-Pillar Gates is after the bridge, before the areas started. Entering the Guardian Gate leads into the Lower, passing into the Non-dual Gate reach to the Middle and finally the Upper in the west. Between the Middle and the Upper there is a stone Pagoda.

Based on the Buddhist texts, I suggest the different interpretation to the building arrangement of this monastery compound unlike conventional scholar's reference on divided three levels, upper, middle and lower, of the temple complex is generally known. It would focus on space rather than level. It was built to describe the one Lotus World of Three Buddha's, and the Great Sea of Avatamsaka. The Virocana Buddha is enshrined in the Great Light Hall on the highest part of the centre area, to the right, Shakyamuni Buddha is in the Precepts Platform, and Amitabha Buddha is enshrined in Paradise Hall to the left of Virocana. Other halls and shrines are located toward their relevant Buddha independently but relatively. It shows the one stanza of Ocean Seal Diagram: in one is all and in many is one; one is identical to all and many are identical to one. It shows the complete and perfect mutual interpenetration of between phenomena and phenomena.

3.1.2 Haein-sa

Haein-sa is said to look like a great ship on the ocean of Gayasan and it is considered to be an auspicious site from the point of view of geomancy. Famous for the stunning beauty of its craggy peaks and peaceful valleys with burbling streams lined with lush foliage, Mt Gayasan is named after a mountain in Buddha Gaya, India, where Sakyamuni, the Historic Buddha, attained enlightenment.

It is unreasonable to expect a safe voyage to build a building to break the balance in the whole Mountain area based on the geomantic concept.

3.1.3 Songgwang-sa

The name of Songgwang has several legends. First, it means a temple in which 18 great monks will spread the teachings of Buddha. In other words, 'Song' indicating '18 great men' means 18 great monks, and 'Gwang' indicating the wide spread of Buddhism means a temple in which 18 outstanding monks will expand the Buddhism extensively.

As one of the legends explains and since it is representative monastery of Sangha community, Songgwang-sa should appreciate the Sangha tradition. The master's Portrait Hall is more important than the main Buddha Hall. The new main hall is too large to keep the entire balance and destroyed the whole landscape.

3.2 Conservation and Restoration: Contemporary Design in Historic Context

The point of intervention or contemporary designs in historic context will be focused on here. It is influencing the existing building arrangements and of some points of supplementation for the future conservation and restoration of the heritage architecture based on the original concept and situation.

3.2.1 Buddhist Treasure Museum, Dharma Talks Hall, and Temple Stay Retreat Centre of Tongdo-sa

Buddhist Treasure Museum of Tongdo-sa is situated immediately after entering the Monastery Compound. It is the seven-kan in the purlin direction and three-kan in the transverse beam direction of reinforced concrete buildings which was built on the site of demolition of the previous traditional wooden office building for the monastery. Modeled after the traditional wooden Structure, it was completed in October 1987 by the Abbot, Venerable Wonmyeong with exhibition area of ca. 270 square meters. It will be the predecessor of the current Museum which is under construction. After the new museum is completed it will be used as a fifth exhibition space.

Dharma Talks Hall is a rectangular in shape with the nine-kan purlin direction (dori-kan) and eleven-kan transverse beam direction (bo-kan) of huge building with hipped and gabled roof. In comparison to the other buildings, it is too large and so destroys the balance of the whole arrangement of the monastery.

The new Temple Stay Retreat Center is a training facility that can accommodate five hundred guests. They are equipped with modernized shower, toilet facilities other than the large scale assembly hall which can be used as a group retreat and congregation for the Dharma Talks. There are currently used as a Temple Stay retreat, training, practice spaces, and the facilities for such as forests memorial services.

3.2.2 Gu-Gwang-Ru Pavilion, Meditation Hall, and Bo-Gyeong-Dang of Haein-sa

As *Gu-Gwang-Ru* Pavilion is just below the main Hall, it was originally meant for those gathered for chanting and for listening to the Dharma talks, and since the Main Buddha Hall, is rather small (in those days), it was kept for monks in early times. The name, Gu-Gwang-Ru, means a building of nine lights, originating from the Flower Garland Sutra. In the Sutra there is a story, which tells that whenever the Buddha gave a talk at one of nine places, a light radiated from his forehead just before he began to talk. Though this building is in the center of the whole Temple, It is now used as a treasure Hall to keep a Buddhist treasure of Haein-sa.

Seonwon, the meditation Hall of Haeinsa, was originally planned to the new place for housing the wood blocks of the Tripitaka Koreana since the late President Park, was concerned about the fire hazard of the old depository of Tripitaka Koreana. But this magnificent reinforced concrete building was found to be inadequate for the Tripitaka Koreana woodblocks and so was left neglected until in 1983 when it was turn into a new meditation hall.

Bo-Gyeong-Dang, Buddhist Gathering Hall, was recently constructed for various ceremonies and meetings. In comparison to the other buildings, it is rather large and so spoiling the balance of the whole juxtaposition of the different buildings. However, having an ample basement space, it proves useful.

3.2.3 Main Buddha Hall, Sangha-Jewel Hall, Buddhist Treasure Pavilion of Songkwang-sa

As the Main Buddha Hall of Songgwang-sa was destroyed by fire in 1951, the present Main Buddha Hall was completed in 1988. The three main images and Bodhisattvas are enshrined in the Main Hall: the past Buddha, *Dipankara*; the present-day Buddha, *Sakyamuni*; and the Future Buddha, *Maitreya*; Along with the Buddhas, Manjusri (the Bodhisattva of wisdom), Samantabhadra (the Bodhisattva of action), Avalokitesvara (the Bodhisattva of Compassion), and Ksitigarbha (the Bodhisattva who helps suffering people). It has a unique roof design with the structure of Chinese character ‘Ah' composed of the front 7-*kan* purlin direction and the 5-*kan* transverse beam direction. In the main hall of Songgwang-sa with about 108-Pyeong (one Pyeong is the area of 1.8m x 1.8m, we do not use this measurement system anymore but the monks tried to put importance of the number 108 vows in Buddhism),

The present Sangha-Jewel hall used to be the main Buddha Hall before the huge present Main Buddha hall was built. It relocated from the site with the method of dismantling and reassembling technology. It displays Sakyamuni Buddha, 10 disciples, 16 arahats, and 1,250 Bhikkus by reproducing Yeongsanhoesang. It is a building symbolizing Songwang-sa as the Sangha-Jewel Monastery, and The Ox-Herding Paintings are drawn on the left and right walls. Especially, the fifth painting, Ox-Herding, means cultivation of mind and has a close relationship with *Mokwoogapoong*.

Buddhist Treasure Pavilion was built as the genealogy library of Songgwang-sa; many legacies including two national treasures are kept at present.

3.3 Towards the WHL as a serial nomination

To fulfill the requirements to be on the World Heritage List, sites must be outstanding universal value and must meet at least one out of selection criteria, which are explained in the Operational Guidelines for the Implementation of the Heritage Convention, and Original Historic context should be mindfully promoted in the contemporary design and intervention.

When the interventions took place, the new design met only the superficial requirements, missing the essential part of conservation. Due to the aforementioned shortcomings, the Three Jewel monasteries failed to be included even in the potential list, while they are distinguished with their outstanding universal values.

If and when listed as a serial heritage sites, these temples will gain the access to a far better maintenance and conservation in the future.

CONCLUSIONS

A constructive step for us all to take would be to consider the idea of initiation of principles and guidelines for the conservation and restoration of three Jewel Monasteries, the idea of good design intervention as a conservation strategy and the idea of proper classification of the heritage category based on its classification system in Korea. A well-funded research with advanced method should be conducted to achieve the documentation of the Buddhist three Jewel monasteries conservation and to ensure management under ideal circumstances with guidance of the new design attached to the three jewel monasteries:

Suggestions are:

1) Research and document these Buddhist sacred sites in the appropriate manner.

2) Revalue the Architectural Heritage of each Monastery as same level of State-Designated Heritage as 『National Treasures』 [9] and whole complex as a 『Scenic Sites』 or a 『Historic Sites』 [10]

3) Recommend as a serial nomination for a World Heritage Site.

These sites would have sufficient qualification in becoming a well managed sacred place if these could be realized.

REFERENCES

[1] Year-numbering system CE means "Common Era," BCE is "Before the Common Era."

[2] The diamond signifies the importance of the receiving and keeping precepts with a strong and solid mind.

[3] The term '*kan*' is generally used to name the bay of the two columns and in Japan it is used for inner space between two columns. The size of the *kan* varies according to the entire size of the building and the dimensions of the wood. Unlike the main buildings of the palaces or the temples, the measurement unit *kan* in a residential house refers to the square space created by four posts.

[4] The name *Jogye* has been adopted by the representative leading order of the present day Korean Buddhism, and the heritage of cultivation has been handed down.

[5] *Hwadu* usually translated as "head of speech" which means "true speech." In Korean Buddhism the traditional method for meditation called "*Ganhwaseon*" is used. Korea is the only Nation where the traditional meditation using Hwadu is generally practiced. The purpose of practicing Seon meditation is awake to the mind. - From the Way of Zen by *Kusan* Sunim.

[6] Hasadang Hall consists of three-*kan* in the purlin direction and two in the transverse beam direction. It is the remaining oldest structure as the monk's living quarter reflecting the life of

the monk in the early Joseon Dynasty. The two kans in the left are heated-floor and the one in the right is a kitchen. Exceptionally, the kitchen has a rectangular opening to the roof and an air ventilator on the top which are not found in other buildings. The structure is common in southern area.
[7] After his enlightenment, Sakyamuni Buddha frequently visited Mount Gridhrakrta near Rajagrha, the capital of Magadha where he gathered an assembly of disciples and propagated his teachings. This mountain is called the Vulture Peak because of the shape of its peak.
[8] The Ten Ox-herding Paintings describe the path to enlightenment and self-development in the Seon tradition.
[9] National Treasures: Heritage of a rare and significant value in terms of human culture. They are tangible cultural heritage of important value, such as historic architecture, ancient books and documents, paintings, sculpture, handicraft, archaeological materials and armories.
[10] Historic sites: Places and facilities of great historic and academic value that are specially commemorable (eg: prehistoric sites, fortresses, ancient tombs, kiln sites, dolmens, temple sites and shell mounds), Heritage Classification, Cultural Heritage Administration, Korea (www.cha.go.kr)

Heritage Classification (the Cultural Heritage Protection Act, CHA, Korea, Jan.29. 2015)

<table>
<tr><td rowspan="11">Designated Cultural Heritage</td><td>City-/Province Designated Heritage</td><td>State-designated Heritage</td></tr>
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<tr><td>Natural Monuments</td></tr>
<tr><td>Folklore Cultural Heritage</td><td>Important Folklore Cultural Heritage</td></tr>
<tr><td>Intangible Cultural Heritage</td><td>Important Intangible Cultural Heritage</td></tr>
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<tr><td colspan="3">Registered Cultural Heritage : Cultural Heritage of early modern Times</td></tr>
<tr><td rowspan="2">Undesignated Cultural Heritage</td><td colspan="2">General Movable Cultural Heritage</td></tr>
<tr><td colspan="2">Buried Cultural Heritage*</td></tr>
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PERCEIVING CULTURAL HERITAGE BY RE-INTERPRETING NEW URBAN SCENARIOS. THE DESIGN OF A *GREEN TERRACE* IN A CORE AREA IN FLORENCE

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Keywords: Cultural Heritage, Urban Regeneration, Sustainable Public Space, Green Terrace

Abstract.

Introduction:

The aim of this paper is to stress the methodology for the regeneration of an open public space by preserving the cultural heritage and by addition of some new elements to achieve quality and urbanity. The paper is dealing with the regeneration of the Piazza de' Ciompi in Florence and the design of a green terrace. The square is located in the inner city and it is well known for the presence of an old market. Although the site is not so much extended provides an overview of functions such temporary marker structures, schools and public gardens. Currently, the site has a lack of urban quality and its morphology is the result of a long process of formation while is still in evidence the strong social character of the area.

Developments:

The regeneration process takes under consideration all factors affecting the history of the site, the physical characteristics such as the existing street grid, the arrangement of the urban blocks and buildings' typology. Therefore, the aspiration for a sustainable place-making is mostly the preservation of the existing, the revitalisation of the old square and the adaptation of the green terrace as a new structure. Finally, the adopted design principles run together with the attitude to obtain the best performance of the new intervention.

Remarks and Conclusion:

In this contribution, it is outlined that one of the main design key principles on which to base the proposed project of a green terrace is the understanding of the context throughout the analysis of synchronic and diachronic evolution of the existing urban blocks and historic gardens to suggest permeability. Additionally, it is underlined how the re-interpretation of the urban pattern related to the historical character of the site can determine the key masterplan issues, leading to the design of the green terrace and the transformation of the area into an attractive and fully-integrated part of city.

1 INTRODUCTION

The revitalisation and enhancement of an urban space in historic environment can turn cultural heritage into an essential local regeneration matter. Historical environment can become the development incentive if it could be interpreted properly and promoted to create attitude towards a special spatial design. Urban regeneration within cultural heritage can be better reached through urban morphology whereas existing urban pattern is still easy recognised. Reflexion on identity of historic context can be seen as a resource for designing new spaces and places for people. Therefore, intervention on cultural and historic heritage requires new methodology in doing and new tools on creating the new urban scenarios. Accordingly, successful place-making implies new approaches in planning and design.

As this paper is dealing with the re-design of Piazza de' Ciompi in Florence some questions should be done as follows: How urban identity and urban characteristics of a heritage place can be considered for the change Which elements have to be considered in designing sensitive places? Which urban and architectural elements can ensure the good and sustainable design?

Therefore, the main aim of the intervention is to create a new urban condition in order to in-crease local liveliness, vitality facing the complexity of uses within the old square. Moreover, the place configuration presents rich elements of existing urban fabric with historic built environment that overlooks the square. The proposed project including the location of the green terraces explores the potentiality of the market place as catalyst for urban regeneration. It exemplifies how such settings can be achieved through land use replacement and spatial optimisation.

2 THE *PIAZZA DE'CIOMPI* WITHIN THE CITY CENTRE

2.1 The historic character

The place is a core square located within *Santa Croce Quarter* in Florence and it was occupied by the *Santa Croce Friars' Gardens*. The today's square is the result of a long process formation but is mainly formed within the '30s after the demolition of some historic buildings. It is obvious the strong relationship of the square with the rest of the City Centre But its urban form take place clearly in the '60s according to Raphael Fagnoni's project for the reconstruction of the *Loggia del Pesce* located in another part of the City and by the latest urban renewal undertaken by the *Ardigo-Michelucci* Local Plan in 1968. The Local Plan aimed to lead directly to *Piazza Repubblica* and to make a visual axis towards *Piazza Duomo*. However, the place even of a strong historic and urban character currently hosts the temporary old structures of the flea market, various associations and clubs, the National Educational Museum and the two public gardens around it used for cultural and leisure activities. There is some of cultural movement especially during summer. Currently, *Piazza de' Ciompi* represents the laboriousness of the district and its popular character in strong contrast to the representative role of the nearest monumental image of *Piazza Santa Croce*

2.2 The understanding of the place

A regeneration process regarding a sensitive core area requires a full understanding of the existing, a full consideration of the urban reality that can achieve the proposed project. Therefore, it is necessary to put design aims with the attitudes of the purpose to obtain the best performance of the intervention**.** The reconstruction process of the formation of a site, the hierarchy of streets, the relations between streets and building type, the formation of the urban blocks one can find the design principles to shape the project. The site's urban form has been constantly in transformation since the regeneration advanced by Fagnoni and the so-called *Lodges of Craft*s aimed to enhance the identity of the district and its popular character considering into the project the historical connotation of the context, its values and limits**.** It is after the reconstruction of the Lodge that appeared the putting in place of the Flea Market. So, *Piazza de 'Ciompi*, is currently the public space which is defined by two important historical elements as the *Loggia del Pesce* and *Palazzo Gerini*. Anyway, throughout the time can be defined as the result of the contamination between old and modern in which the quality of the heritage has to be considered positively within the designing of the new.

Figure 1: Piazza de' Ciompi in Florence as it is. A view of the Flea Market towards Piazza del Duomo

Certainly, the many existing functions and the chaotic traffic image around the square need a re-organised in order to overcome the today's lack of urban quality. The market place, in fact, represents the much neglected core public space that provides opportunities for the *locality* to emerge in a context where the most ordinary conventions are staged as authentic traditionalism.

2.3 The re-interpretation of the existing urban pattern

Through an appropriate reading of the cadastral survey, found in Florence Historical Archive , regarding the whole building stock of the urban block number14 and performed around 1936 just before the demolition, is made possible to identify the urban blocks and the individual house types. On the cadastral plan is well revealed the existence of a covered canal sewer, believed to belong to the Eighteenth Century. We have a proof of the existing open canal in some historical documents: The oldest testimony is given by the City of Florence Plan, dating between 1594-1624, held at the Historical Archive. Canal's existence is also recorded by the next City Plan dating in 1690 but there are no traces of such canal in subsequent historical maps, probably covered. Appropriate reading of the historical documents giving also the testimony of the old *Santa Croce Friar's Gardens.*

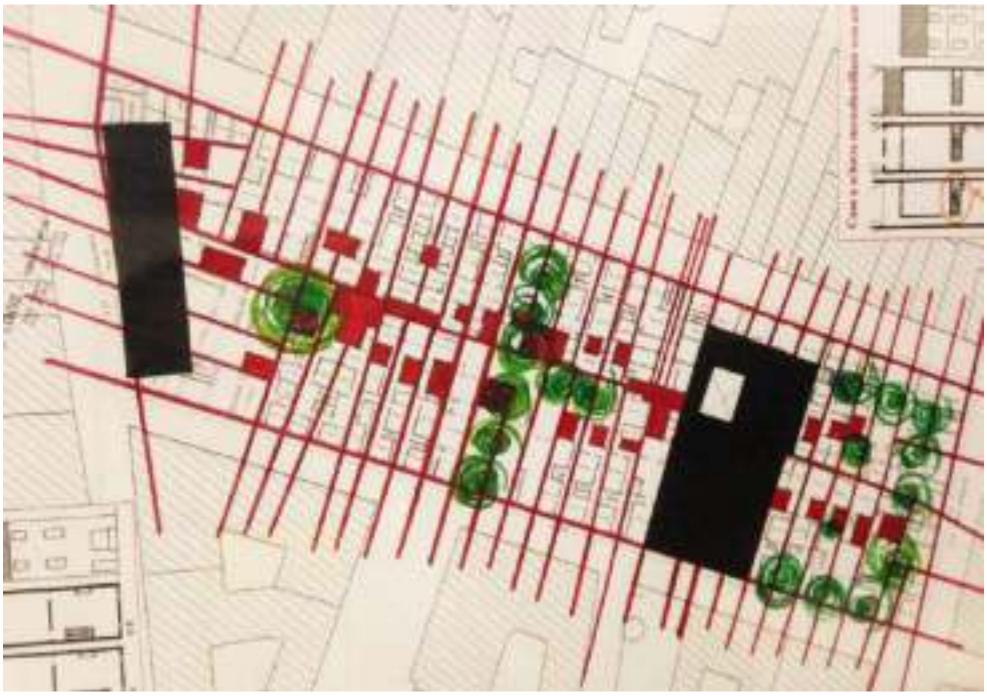

Figure 2: Piazza de'Ciompi. The proposed new open and green spaces are designed on existing street pattern

All these aspects of historical understanding of existing urban pattern is related to the character of the place. Consequently, clearly emerges the design intention to re-interpretate the historical memory and identity of place as a guide for actions to be considered within the regeneration design. Consequently, the old pattern is in evidence within the proposed mastreplan that based on an overall grid and a water route that follows the line of the old ca-nal while all proposed new green spaces will take the place of the old Friars Gardens.

2.4 The leading factors for re-designing the place

Historically, the market place had been enclosed by the built-form on the sides of the square. However, this sense of enclosure had been eroded by the demolition of the previous buildings on the site and the human scale of the space was lost, leaving an open, desolate, rarely-used area. Therefore, the main aim is to regenerate the area whilst respecting the surrounding listed buildings and other buildings of architectural interest. The views of Santa Croce Church and the visual of the Dome of Brunelleschi have to be reinforced by the new structures as well as the relationship with the Lodges of Crafts . The new green terraces will help to meet city centre residential requirements. Tenants of the residential buildings will have a longside seat for regular activities, including an easy access to the adjacent National Museum of Education, as well as an offer of new services

3 THE REGENERATION PROCESS

3.1 The Strategic Guidelines

Research and analysis were integrated into the design by creating a strategy to satisfy the objectives of promoting a spatial design and accessibility to support the social interaction. The following objectives were parameters determining the form of the spatial interventions on the site interacting with the surrounding areas. The design also sets guidelines to give incentives for a healthy lifestyle, community, and economy:

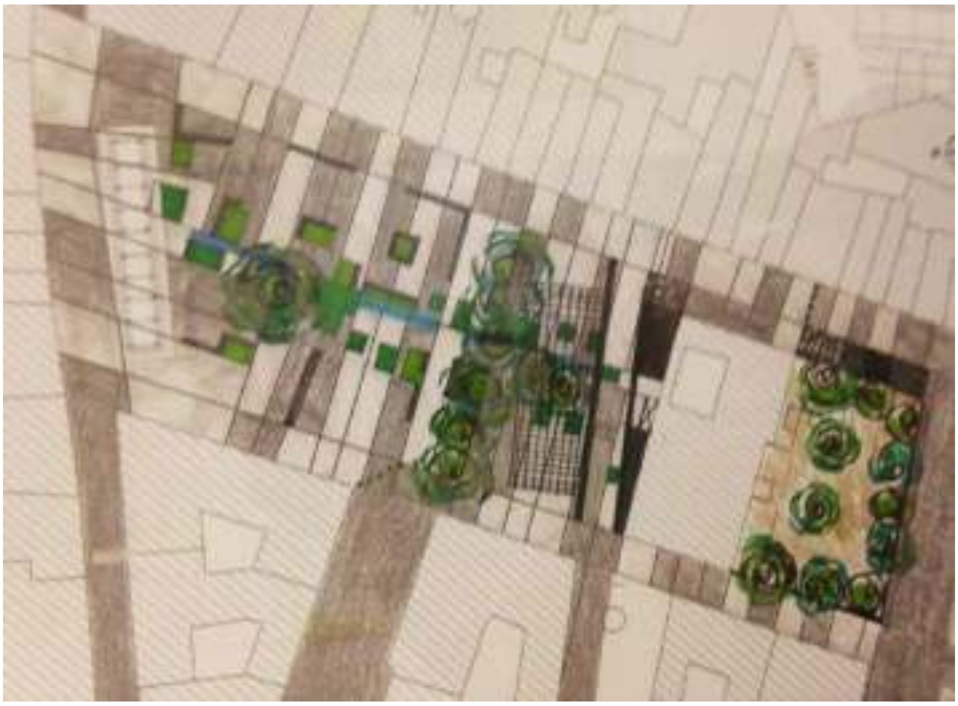

Figure 3: *Piazza de'Ciompi*. The proposed Urban Framework and the location of the *green terraces*

- Promote and evaluate the historic *Loggia del Pesce* and *Palazzo Gerini* , now National Museum of Education
- Make a core area giving a functional and configurative sense of place
- Identify a grid pattern as a guide for the urban design and space management
- Achieve a full pedestrian area and new car parking areas
- Integrate the square with the existing *Gratta* Garden and *Chelazz*i Garden
- Put new structures to encourage services and make sense of socialisation and relaxation
- Multiply green spaces and green spaces to improve the bio-climate conditions on the site
- Re-design the back side of the *Palazzo Gerini* and the replacement of the existing fire escape stairs
- Design *green terraces* to balance the whole regeneration process giving the right importance between functional and structure configuration.

3.2 The design approach to the master planning process

A four-step approach is taken to develop a framework within the following:

- Identify poorly maintained market place that has potential to become productive and support various activities as well
- Transform existing green spaces into garden-shares and recreational spaces for young and elderly people
- Create connections between green spaces focusing on accesses for pedestrians and cyclists

Figure 4: *Piazza de' Ciompi* and the proposed Master plan. The two *green terraces* are located on the opposite side of the *Loggia del Pesce* and in front of the *Palazzo Gerini* to create enclosure, continuity and sense of place

- Develop a core site design that implements new social and recreational community facilities, mixed-use, and renovation of existing residential buildings. The master plans should create and link green spaces together with the two *green terraces* by providing new areas to produce spaces vending and mending. All connections and accessibility should be well-integrated from the broader community into the site.

Through this four-step approach within the Piazza regeneration should be possible to transform the current chaotic core site into a sustainable space that generates a stronger sense of place, identity, urban configuration, mass and scale in new structures where social and physical activities can take place.
The aspiration for the regeneration project and the restoration and enhancement of the memory of the square, is generated partly from the situation prior to the '30s and before demolition into its new social, economic and cultural new condition. The framework identifies a new configuration of the market place that is based on grid pattern following the old urban fabric of the demolished urban blocks.

3.3 The proposed Masterplan

Indeed the proposed Masterplan follows the track of some key elements on which to base the project. Some, well-known Caniggia studies on urban morphology, have shown various *synchronic and diachronic* development of the Florentine characterisation types of houses forming the urban blocks. So, through the study of the typological process of the terraced houses, as accomplished in 1936 and as it is found in the historic plans, it was easy to find the traces of transformation over the centuries of the urban blocks to take into consideration for the design of the Masterplan. Although the medieval fabric was complex, the variety of the grid is formed by the presence of rectangles of different sizes, some very lengthened due to the type of former houses and others different whose aspect ratio is not very high because of the union of two houses. The proposed urban design allows diversity of spaces for meeting and relaxation, green spaces and water, space for children to play or for elderly people with a small car-park and public convenience block dominating to the Southern side of the square.

In detail, the design principles taking into consideration:

Figure 5: *Piazza de'Ciompi* as is proposed. The re-designed old market place can create a sustainable urban landscape and improve micro climate on the site

- The protection of the character of the place encouraging the development of new construction using all environmental dynamics and recognising all needs of local community
- The using of the urban grid by replacement of the former urban blocks with a geometric pattern-colored strips
- The creation of new green spaces replacing the old form of the Santa Croce Friars gardens with a waterway as memory of the old covered canal
- The construction of *green terraces* with roof garden located on the opposite side of the *Loggia del Pesce*, that goes to close the visual image of the square and to create an "architectural continuity"
- The creation of children play spaces and other spaces for elderly people, as meeting points with cafes and other services on the ground floor of the *green terraces*
- The pedestrian re-organization and the creation of parking areas
- The use of materials and urban design elements in accordance with the existing colors of the square.

3.4 The objectives of environmental sustainability

In order to create a good open space and to make regeneration in accordance with sustainability criteria, environmental benefits are taking into consideration as follows:

- Creating the sustainable form protecting historical, architectural and aesthetic landscape arising from complexity of relationships between built environment and green strips
- Optimising thermal comfort on the site between existing buildings and open spaces in order to promote liveability of place
- Minimizing the consumption of energy using sustainable materials with low environmental impact in order to reduce *ecological footprint* of design on the ground
- Rationalising the use of water to create favorable micro-climate conditions
- Minimising and mitigate the noise and air pollution and toxicity of materials that can affect quality of life in the site
- Optimising the allocation of services in terms of sustainable usability
- Ensuring the morphological quality of the site, the proper location and configuration of the new structures giving a real value from architectural and aesthetic point of view.

4 THE GREEN TERRACE AND ITS CONCEPTION

4.1 The setting

At present, the lack of a place for social gatherings is in evidence in *Piazza de'Ciompi*. However, it is essential to underline that in the last decades there is a lack of urban quality around the Piazza. The degradation of some important points in the historic context as well as the insufficient of good designed pedestrian areas and open spaces, unable to ensure the safety of children and the elderly are the main reasons for the re-design of the site and the location of the *green terrace* in the back side of *Palazzo Gerini* and at the square closure of the old Flea Market. Surely, within the proposed Masterplan it was clear , since the beginning, the intention to create permeability and accessibility in the site that should be improved by removing the existing parking spaces. On the other hand the creation of environmental-friendly streets was one of the main goals to be reached as well as the removing on street parking to slow down movement to enhance vitality. Additionally the creation of pedestrian crossings is proposed with temporary open market places including a street market, socially more inclusive.

Design strategy is limited to minimise the control of over activities but the public realm is planned for uncertainty diverse space-types including green terraces, covered, semi-covered and open-air spaces helping adaptation of the numerous options for artistic expression. The re-designed green spaces as front yards of the surrounding residential houses are leaving potentiality for creation of urban quality. The revival of the area is approached by designing the two *green terraces* with small service units above and resident basement-parking below. It was intended to recapture the spirit of those structures and their relationships to the adjacent church of *Santa Croce,* keeping the visual to *Piazza Duomo*.

The structures within the market place environment should improve the recreating historic form, using quality of materials and modern build methods, to establish a friendlier, more intimate, and therefore more widely-used, space. The *green terraces* can guest smaller vending and mending spaces and can also provide space for sharing food and urban gardening. The urban gardens on the old square will be connected by paths for pedestrians and cyclists, which increases the walkability of the area. A successful implementation of the objectives will generate incentives for healthy lifestyles, creating urbanity.

4.2 The *green terrace* and its design concept

A reference for the design of the *green terrace* is the shelter built by the Manuel Arguiyo for Plaza Largo da Devesa in Castelo Branco in Portugal. The *green terrace* is proposed to be

Figure 6: *Palazzo Gerini* and the proposed *green terraces* that should create urbanity on the site. The curve form ideally embraces the old market place square while keeps perspective to *Piazza del Duomo*

a solid block of reinforced concrete, supported by tubular steel pillars; the floor of the terrace is set to 6.80 m elevation dictated by the openings already existing on the Northern front of *Palazzo Gerini*. The system of both proposed *green terraces* are placed so to suggest a path, having variable inclination and six holes through are standing the existing trees, giving a characteristic form to the new structures.

The particular shape of the curve, which ideally embraces the square, plays an important role on keeping perspective with the *Dome of Brunelleschi*. Additionally, the new structures will be important as a connecting element between the *Loggia del Pesce* and *Palazzo Gerini.*

4 CONCLUSIONS

- The proposed urban design takes advance of historical implication of the existing historic context, and the need for new urban and architectural values.
- A careful understanding of the urban reality in order to match the design intentions withthe attitudes of the main goals is essential to obtain the best performance of urban regeneration in historic environment.
- The consideration of the existing urban form value plays an important role on re-designing the place.
- Lessons learned from the past as the typology of buildings are useful to catch the design framework.
- The importance of a strategic vision is to create a lively, welcoming place that is surrounded by high quality buildings that animate the edges of the street and draw people into the green spaces
- The proposed re-design of the old market place can be useful to create the overall vision and the removal of the physical barriers between the market place and *Palazzo Gerini*
- Good urban design can give residents equal opportunities to improve their quality of life in a multi-dimensional way; Promoting *green terraces* for social interaction involving proper master planning and designing green spaces to ensure community healthy lifestyle

- The design reveals how a physical design and social scheme can be simultaneously implemented as sustainable approaches where both community and economic needs while providing healthy incentives.

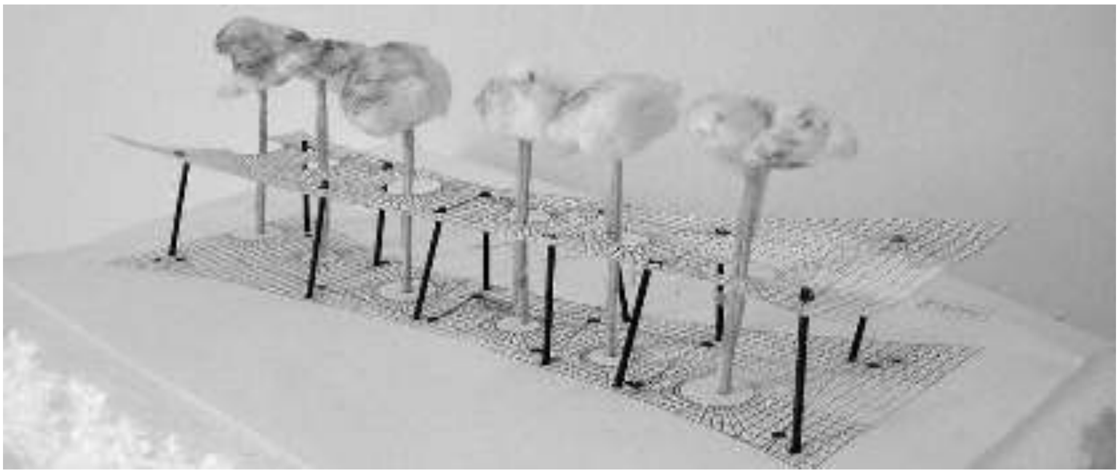

Figure 7: The proposed *Green Terrace* and its structure. The six holes are giving to the new structure its characteristic form and are designated to preserve the existing trees on the site

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NOTE

This paper is developed within the research Sensitive Interventions in Historic Environment planned and coordinated by Dimitra Babalis at the Department of Architecture, University of Florence.

SPATIAL POTENTIALS AND FUNCTIONAL CONTINUITY IN HISTORIC BUILDINGS

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Keywords: Historic Buildings, Reuse, Spatial Analysis, Spatial Potentials, Functional Continuity, Compatible Use

Abstract.

Introduction:
The conservation of historic buildings can include a wide range of approaches but existing conservation theories recommend reuse of buildings, which ensures the continuity of their life. Generally historic buildings are subject to interventions that blend a combination of uses. As a result different parts of the building are subject to different periods of change and in time we usually observe a detachment between spatial and functional continuity.

Developments:
This paper aims to underline the importance of functional continuity related to the spatial potentials of historic buildings. Understanding spatial potentials needs a deep involvement to the building so spatial analysis can be regarded as the initial step in defining a compatible use for historic buildings. Therefore, at the first part of the study, spatial analysis is structured to understand and evaluate buildings in terms of contextual ties, tectonic order, geometric relations, spatial organization and spatial circulation. After spatial analysis, spatial potentials are evaluated in relation to activities and functional continuity. Both spatial analysis and functional continuity are discussed through a case study in Ali Pasa Han, which is a typical Ottoman Han on the historical peninsula of Istanbul.

Remarks and Conclusion:
While identifying compatible use or uses for a historic building, functional continuity needs to be evaluated as one of the basic design criteria in order to retain its cultural significance. This does not mean that a historic building needs to be used for similar activities but it should be used for activities all in relation to each other in terms of spatial experience. Because a historic building can fully reveal its potentials only if it is evaluated and experienced as a whole.

1 INTRODUCTION

The historic environment is subject to change including buildings and all their interiors and adaptation is an inevitable outcome of this process. According to the Burra Charter [1], adaptation means changing a place to suit the existing use or a proposed use. Use means the functions of a place, including the activities and traditional and customary practices that may occur at the place or are dependent on the place.

According to its context and spatial potentials a historic building is usually used for more than one purpose and activity. Therefore certain parts of historical buildings are more subject to change because of their roles and relatively high spatial potentials. In historic city centers ground floors are the most privileged parts of buildings because of their increased accessibility as the continuation of open-air public spaces. Therefore ground floors are subject to great changes while upper floors are used with relatively little change. So periods of change for different parts of a building change greatly according to their potentials. As a result most of the historic buildings are subject to interventions that blends a combination of uses. These interventions that cover only certain parts of a building can be regarded as partial reuse attempts. If we consider the togetherness of all these interventions, we can say that most historic buildings are used for mixed purposes. At this point we need to consider the relationship of all these different purposes and activities that take place in the building. Because functional organization has the potential to change the way a building is experienced and the discontinuity and segregation of activities within a building can ruin its cultural significance.

This paper aims to underline the importance of functional continuity related to the spatial potentials of historic building. Therefore understanding these spatial potentials needs to be considered as the initial step in defining a compatible use for historic buildings. In order to determine a compatible use for a historic building the most important objective is to understand its cultural significance. But understanding the cultural significance of a building needs a deep involvement to it. So, spatial analysis can be regarded as the initial step in determining compatible use and defining the priorities and limitations of the intervention in adaptive reuse.

Spatial potentials are mostly defined by the innate and unchanging properties of the building and they are very important in order to understand the cultural significance of the place. So, this work develops a framework to understand the spatial potentials and discusses the importance of certain architectural and spatial factors through a case study in a Han in Eminönü, Istanbul. After discussing the spatial potentials, the building is evaluated in terms of the relation between functional continuity and spatial potentials.

2 ANALYZING HISTORIC BUILDINGS FOR UNDERSTANDING SPATIAL POTENTIALS

There are many different methods in analyzing architecture, which have different concerns. But the priority of this work is to understand the architectural and spatial potentials embedded within historic buildings and their components. These potentials help us to understand the cultural significance of a building and defining compatible use. The architectural and spatial factors that are going to be discussed in this paper are listed in Table 1. These factors are going to be discussed through a case study in Ali Paşa Han, which is located on the Golden Horn in Eminönü.

Table 1: Architectural and spatial factors used to analyze historic buildings

Architectural and Spatial Factors
Contextual Ties
Tectonic Order and Material
Geometric Relations
Spatial Organization
Spatial Circulation
Spatial Potentials

Ali Pasa Han is one of the most typical examples of Ottoman city hans [2] (Figure 1). Han can be defined as a building typology developed by the Early Ottomans and it served as a roadside inn where travelers could rest and recover from the day's journey [3]. They were usually characterized by identical spaces called cells surrounding a courtyard. As they were situated in the city center, in time most of the city hans in Istanbul started to be used for commercial activities and production related to these activities.

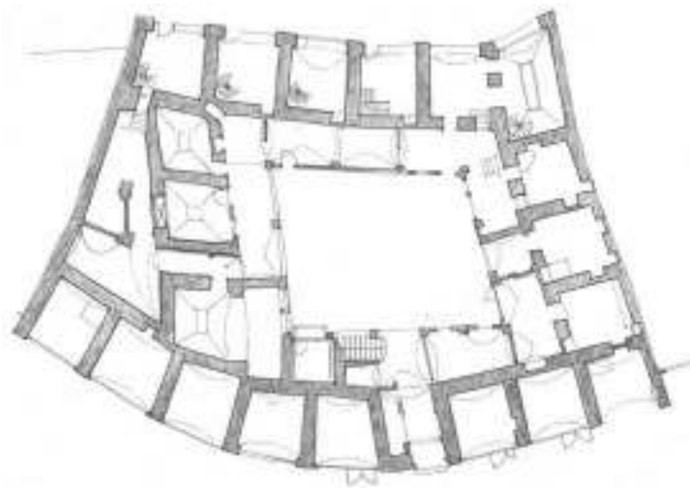

Figure 1: The ground floor plan of Ali Pasa Han (author's drawing)

Figure 2: The section of Ali Pasa Han (author's drawing)

Ali Pasa Han is located in Eminönü on the Golden Horn and it is in a completely commercial zone in which various products can be found. Typical of Ottoman Hans, it is built of stone and brick horizontal stripes. It is a two storey han which has a rectangular courtyard in the middle surrounded by arcades (Figure 2) (Figure 3). The arcades create access to cells. While each cell is of private property, the courtyard is public.

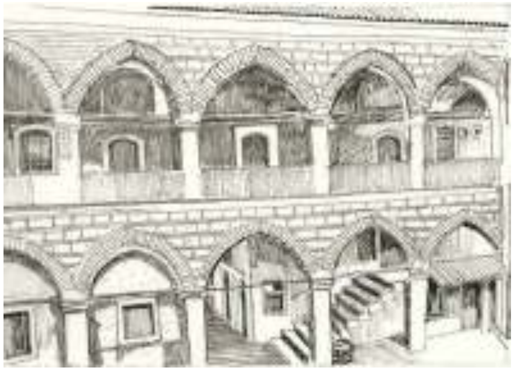

Figure 3: The courtyard and galleries of Ali Pasa Han (author's drawing)

2.1 Contextual ties

In order to understand a building, it is necessary to grasp the exterior forces that shape it. Buildings that are situated in urban context needs to be analyzed in terms of urban continuity. Therefore the relationship of building mass to the urban space in which it is defined in can be regarded as the initial phase of contextual analysis because generally urban space is one of the most important determinants of the architectural shell, which is an interface between the building and the city. Urban infrastructure also plays an important role in the determination of the buildings entrances and orientation. While analyzing the relationship between the building and the urban space that surround it, it is necessary to look at the urban spatial envelope, pre-dominant paths, density, important buildings, structures and landmarks around the building.

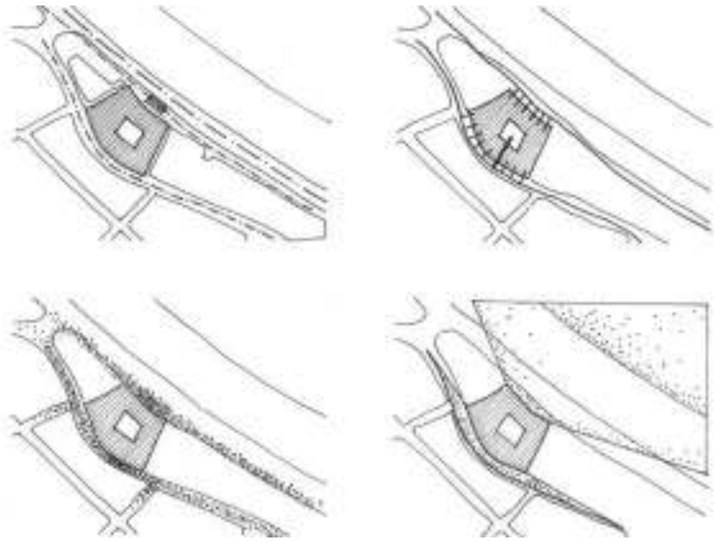

Figure 4: Contextual relations in Ali Pasa Han (author's drawing)

Figure 4 shows predominant paths, entrances, pedestrian density and the area from which the building can be perceived. Although the building faces the shoreline of the Golden Horn on the Northern side, the main entrance of the building is from the narrow street at the South West (Figure 5). But the entrances of all the ground floor cells both on the shoreline and at the back are directly from the street. The density on the shoreline side is considerably high. As the cells on the shoreline are not connected to the courtyard, there is no passage between the streets through the building. So, the building has no direct relation with the main street except the cells facing the street.

Figure 5: The main entrance of Ali Pasa Han from the narrow street on the southern part of the building (author's drawings)

2.2 Tectonic Order

The most important deficiency of today's architecture and spatial design activities can be regarded as the detachment of construction from the realities of matter and craft. According to Meiss [4], in architecture the question of truth and untruth refers to the relationship between form and construction. In this sense historic buildings expose the way they are structured in both elementary and holistic point of view. In most historic buildings especially in those of Renaissance the nature of material was the basic element that determined constructional principles and beauty was the result of the logical proportional relations and constructional principles that respected the nature of material [5].

Material is much more than a follower of form. It is the strongest instrument of the architect in order to create a unique architectural language. Its structural capacity, physical and aesthetic aspects determine tectonic order and constructional principles. As tectonic order is accomplished by material, it is to be analyzed always in relation to material.

Tectonic order arises from the relationship between architectural elements that come together with the principles of gravity. Gravity helps to define a hierarchy, which is vital for the consistency of the building. This hierarchy can be easily read in section starting from top towards the ground by looking at architectural components, elements and the ground. In figure 6, the tectonic order of Ali Paşa Han, can be observed in section. While Figure 7 shows the loadbearing walls, Figure 8 shows the distribution of loads in plan and vault types.

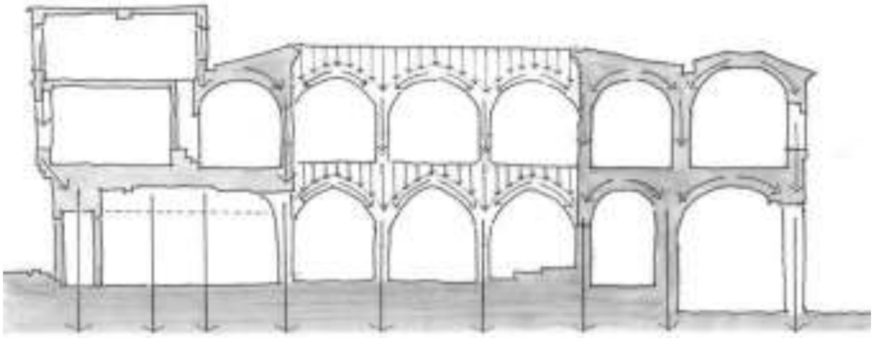

Figure 6: Tectonic order in section (author's drawing)

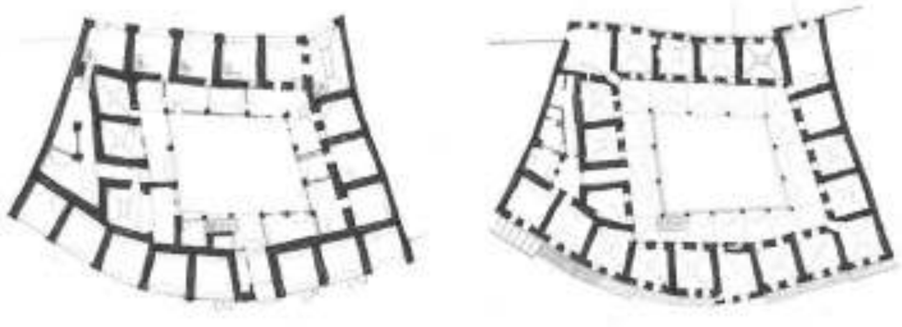

Figure 7: Loadbearing walls in Ali Pasa Han (author's drawing)

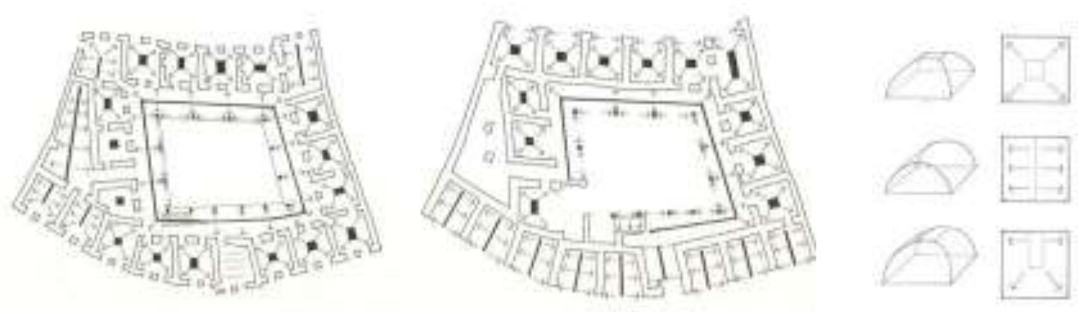

Figure 8: Tectonic order and vault types in plan (author's drawing)

2.3 Geometric Relations

Resolving geometries in a building is one of the most important steps of architectural analysis because all buildings are defined by the togetherness of basic or complex geometric forms and these geometries create spatial forces according to their articulation. The geometric relations of different parts of a building can be discussed in terms of building mass, façade, plan, section and interiors. Figure 9 shows the geometric relations in Ali Pasa Han by focusing on the geometry of building mass and void, the centralized geometric hierarchy, the overall geometric grid and geometries of interior envelopes.

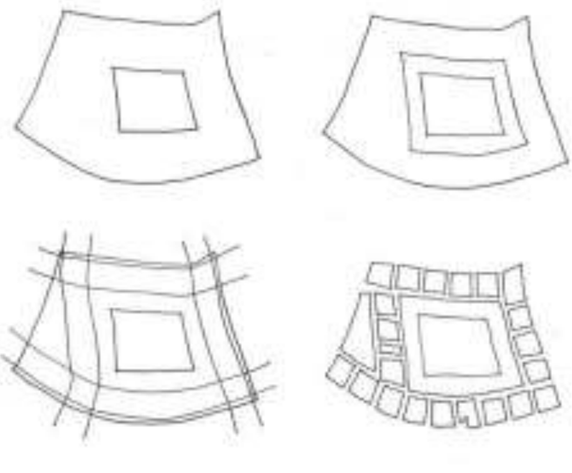

Figure 9: Geometric relation in Ali Pasa Han (author's drawing)

2.4 Spatial Organization

Spatial organization is defined by the relation ship of spaces that make up the building. In a building program spaces with different intentions and priorities come together. In this sense in most buildings there are spaces that are analogous or similar and there are spaces that differentiate from the rest. These differences define a hierarchy and every space is defined in the system by its role. Ching [6], define 5 organization types which are centralized organization, linear organization, radial organization, clustered organization and grid organization. Usually in historic buildings different spatial organization types are used together in order to define spatial hierarchy. In figure 10 above, in the ground floor plan of Ali Pasa Han, we can observe centralized organization around the main courtyard, linear organization through the entrance axis and service corridor. At the figure we can also observe the linear organization of ground floor cells through the streets at both sides of the building. In the same figure below, in the first floor plan we can observe centralized organization around the courtyard and again linear organization through the service corridor.

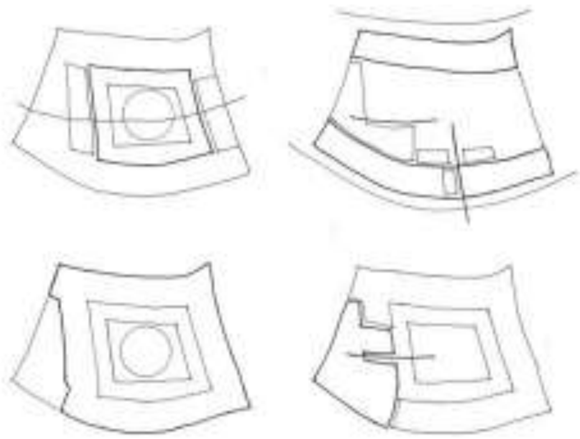

Figure 10: Spatial organization in Ali Pasa Han (author's drawing)

2.5 Spatial Circulation

Spatial circulation is the way or path that is predefined by the architect in order to create hierarchical access for all spatial components in a building. While spatial organization is much more about the relationship of spaces, circulation is about the relationship of paths and spaces. In order to understand spatial circulation it is essential to consider the starting point, the layout and the architectural definition of the path. Figure 11 shows an analysis of the circulation system in Ali Pasa Han in plan. Above we can observe the circulation areas in the ground floor and first floor. Below we can notice the relationship of circulation paths and spaces in both floors. Figure 12 shows the architectural definition and the character of the circulation path on the first floor.

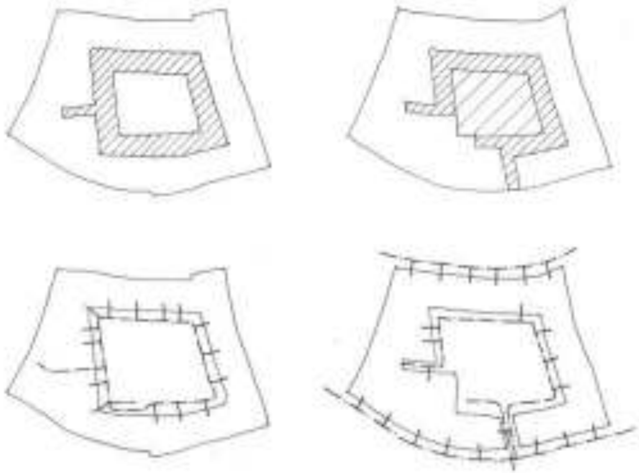

Figure 11: Spatial circulation in Ali Pasa Han (author's drawing)

Figure 12: The architectural definition of the upper floor circulation path (author's drawing)

3 FUNCTIONAL EVALUATION OF SPATIAL POTENTIALS

As the functional organization of a building reflects its role and intention, it is a part of its cultural significance. The Burra Charter (1999) defines the aim of conservation as retaining the cultural significance of a place. According to the Charter, cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects.

A place has no meaning without human activity and function defines the way human interact with space. It is very difficult to preserve all the initial functions of a building but it may be possible to define a compatible use for it. According to the Burra Charter [1], compatible use means a use, which respects the cultural significance of a place. Such a use involves no, or minimal, impact on cultural significance. Where the use of a place is of cultural significance it should be retained. Changes, which reduce cultural significance, should be reversible, and be reversed when circumstances permit.

The initial use of a building reflects its overall intention and its contextual role. The spatial organization is mostly determined by the activities that are predefined in the building program. But in time these activities change according to social, economic and cultural factors, which usually have certain contextual ties. By the affect of these changes, the integrity of the building program start to be dispersed and parts of the building start to be used for different activities. This inevitable fact leads to a certain detachment between the functional and spatial organization of the building.

Functional organization is about the relationship of activities that take place in a building. Just like spatial organization every space has a functional role in the overall functional organization of the building. But there are some innate functional properties that are hard to change. For example a building's functional organization often hinges on delineating service and served spaces. According to Jenkins [7], regardless of scale or segregation degree, delineating and balancing service and served zones remain vital in the life of a building. The degradation between public and private is also another functional property that is hard to change if the fabric of the building is not changed. Figure 13 shows the degradation between public and private spaces in the original plans of Ali Pasa Han. But today on the ground floor we can observe that the initially public galleries that surround the courtyard are closed and isolated from the central courtyard (Figure 14) and they have lost their public character. As these types of interventions ruin the innate functional and spatial character of the building, they need to be removed. And innate functional properties need to be evaluated in order to define the new functions that will take place in a building.

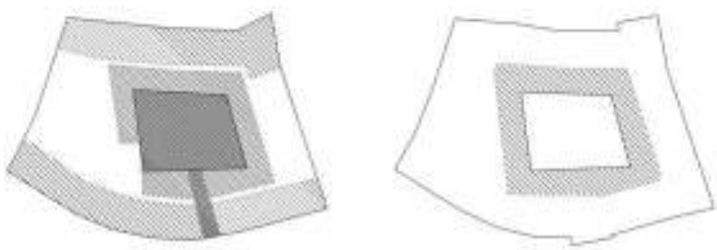

Figure 13: The degradation between public and private in Ali Pasa Han (author's drawing)

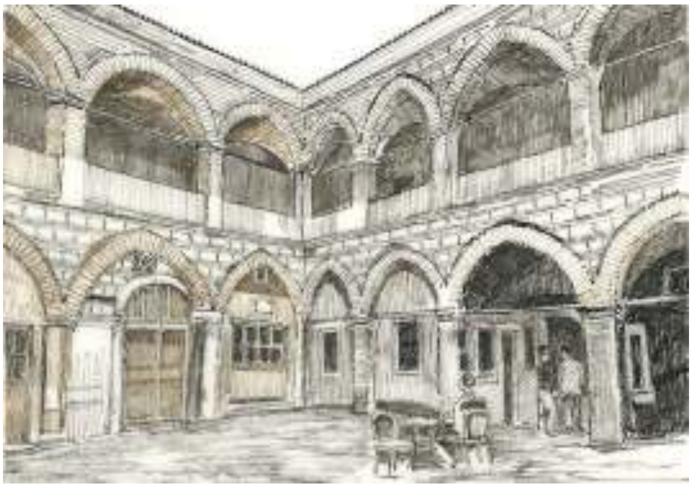

Figure 14: The isolation of galleries from the central courtyard in Ali Pasa Han (author's drawing)

Functional changes are usually concentrated on ground floors because they have stronger relations with surroundings and they are much more accessible than other levels of the building. This privileged situation also has negative effects on the building. Mostly ground floors are subject to great changes while upper floors are used with relatively little change [8]. The differences between the periods of change break the functional continuity between different levels or parts of the building.

Today Ali Pasa Han, also suffers from functional discontinuity. While the ground floor cells around the courtyard are used for production, the cells connected to streets are used as retail units. On the other hand most of the cells on the first floor are empty and the upper level does not live at all. The ground floor units are subject to interventions that all have different objectives and priorities. A historic building situated at the commercial core of Istanbul is used for different purposes and activities that do not have any practical or conceptual relation to each other. The most important reason for this spatial and functional discontinuity is the fact that the cells belong to all different individuals and the way they use space is not organized at all. As a result each cell or unit is modified according to its owners expectations and needs and the building suffers from the lack of overall operative organization.

Ali Pasa Han was given as a task to the students of ITU Interior Architecture III Project Studio during the 2014-2015 Fall Semester. The students were asked to develop a holistic re-use proposal for the building in order to create cultural interaction. As the student group was an international one with several Erasmus students, the theme of cultural interaction also has a practical grounding. All the activities and functions were to be defined by the students. At the first step they were asked to analyze the building in terms of contextual ties, tectonic order, geometric relations, spatial organization and circulation. Then they needed to create a scenario in relation to the context and define all the activities and their relations. After creating the building program, they started to develop their proposals. Most of them proposed to use the ground floor for commercial activities and the first floor for production in relation to the commercial activities on the ground floor. Some of them proposed to strengthen the relationship between the two levels by adding new stairs. The courtyard was mostly used to gather people in order to intensify cultural interaction. Figure 13 shows the proposal of one of the Erasmus students. The student proposed open exhibition units in the cells opening to the main street and created visual relation with the courtyard. The courtyard was used for traditional and contemporary shadow art shows and exhibitions. On the ground floor there was a mixture of ateliers and sales units practically in relation to each other. The first floor was mostly used for ateliers, workshop spaces and cafeteria. The building program was developed in order to create a center to exhibit, design, produce and interpret ottoman patterns on different platforms and products. The interiors were also donated by surfaces and products, which were produced in the ateliers.

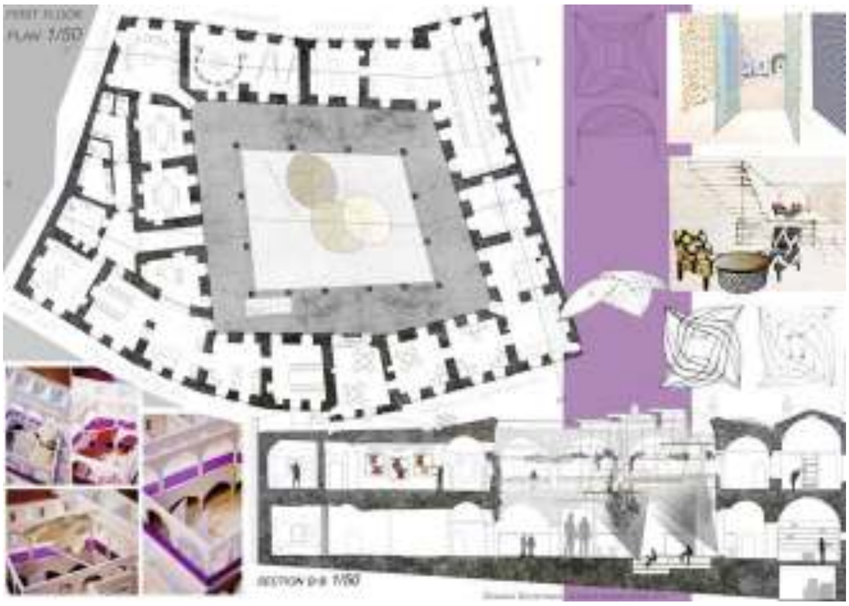

Figure 13: Student Proposal for Ali Pasa, Dominika Szczepińska

4 CONCLUSIONS

Historic buildings are to be given new roles if they can no longer be used with their previous functions. Especially buildings with initial functions of public interest need to be evaluated with a holistic approach in order to maintain spatial and functional continuity. According to the Venice Charter [9], the conservation of monuments is always facilitated by making use of them for some socially useful purpose. Therefore public buildings of historical significance are to be used for public activities all in relation to each other.

Especially in city centres most historic buildings are subject to partial reuse because of the significant potential of ground floors as the continuation of open-air public spaces. When accompanied by a socially useful purpose, this great potential can be regarded as an attraction to increase the accessibility and reveal the cultural significance of the whole building. But as we can also observe in the example of Ali Pasa Han, often the precedence and increased accessibility of ground floors breaks the continuity between different levels of the building.

Historic buildings are characterised by the inseparable relations between form, structure material and function, which defines both their architectural identity and cultural significance. Change may be necessary but is undesirable where it reduces cultural significance. While identifying compatible use or uses for a historic building, functional continuity needs to be evaluated as one of the basic design criteria in order to retain their cultural significance. This is because a historic building can fully reveal its potentials only if it is experienced and evaluated as a whole.

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TRADITIONAL PERSIAN COURTYARD RESIDENTIAL TYPOLOGY IN A NORTH AMERICAN SUBURBAN FABRIC

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University of Waterloo

Keywords: Persian Courtyard House, North American Contemporary Suburb, Immigration

Abstract.

Introduction:
This paper compares traditional Persian neighborhoods with modern North American sub-urban neighborhoods and suggests a design strategy for translating features of the typical Persian court-yard house model into the modern North American suburban context.

Developments:
A case study design seeks to apply the architectural principles underlying a heritage Persian court-yard house to a house set in a contemporary suburban community just outside of the City of Toronto. The key elements that define courtyard houses in historical Persian cities are a connection to nature and an internalized garden, privacy for the family, accommodation for an extended family, and areas in the home set aside for business.
These traditional Persian residential concepts have been translated into a North American context through a case study design for a Iranian-Canadian home with the presence of an internal garden courtyard, solid exterior walls for the home, open circulation within the house, and the presence of work and office areas. Further Persian elements such as wind catchers, a variety of courtyards, and a main entrance (hashti) have also been incorporated into the design study

Remarks and Conclusion:
The ultimate aim of this paper is to evaluate the future of Canadian cities and the way their built forms could evolve if suburban Canadian home building enterprises began to reflect the traditions of incoming immigrant cultures, in the case shown in this study, Persian culture. A consideration of such the social and family needs of such a new culture and the design case study which follows identi-fies and suggests a new social dynamic for existing and new Canadian suburban neighborhoods.

1 INTRODUCTION

This research considers the future of Canadian cities and the way their built forms might be affected by trends in globalization of culture and a more diverse immigration to Canada. The purpose of the design case study which follows is to develop design strategies for establishing a built identity for communities that can be shared by Canadians and the new immigrants seeking a life in Canada. The first step involves reevaluating traditional design in a contemporary context.

Canada has one of the highest numbers of immigrants in the world at 20% of the nation's population. Given the high numbers of new citizens to be, there is a significant potential for cultural effects of such globalization on architecture and the urban form of residential neighborhoods in a suburb like Richmond Hill, a Canadian community in the northern edge of the Greater Toronto Area (GTA). The GTA metropolitan area is home to 57,000 Iranians, who form one of the largest expatriate Iranian communities in the world. An increasing number of these have chosen to make their home just outside the City of Toronto boundaries in the GTA town of Richmond Hill. In the 2011 National Household Survey Profile of the Town of Richmond Hill, 14,415 residents (14.25%) of the town had originated in Iran. This number was exceeded only by the 15,055 residents (14.88%) who named China as their place of birth [1].

This paper focuses on the residents of Iranian ethnicity in Richmond Hill and the urban built forms and functions that Iranians might be expected to maintain and introduce in shaping their neighborhoods. These aspects might include some familiar, common and continuous urban and architectural forms from Iranian cities.

Like the general migration of immigrants to suburban communities when they become established in the new country, large number of the Iranian immigrants described above have relocated from the city proper to suburban neighborhoods, greatly expanding suburban populations. The evolving form that these suburban areas take as they incorporate their new residents is of great interest to Canadian urban planners and architects. The shape of the new suburb that will emerge in such an evolution of the Canadian community will originate in responses to the typical new Canadian's personal life, the life of their family, and their new relationship to society as a whole.

2 A NEW INTERPRETATION OF A HOUSE IN A SUBURB OF TORONTO

An important aspect of architecture is identity, which in part is based on the culture of a people who live in a particular space. Identity initially emerges from the climate, religion, and beliefs of people, and is valued even when members of a culture make a transition to other climates and places. Immigrants generally bring their own background cultures to their new setting and try to adapt those cultures to the new environment. Despite a wealth of immigrants, however, suburban architecture in the Province of Ontario rarely reflects the demographics and culture of people who have moved there and instead is an image of the people who have already lived there for multiple generations. In fact, most suburban areas in this province look similar to each other although, in reality, they are home to many different cultures. In response to this poor fit of housing to populations, this research focuses on the design of a house in a suburban area of Ontario, Richmond Hill, one that incorporates features of a traditional Iranian house. That design exercise, the case study house in this paper, is developed through several stages in which the architectural elements and functions of heritage Persian courtyard houses are transformed to suit contemporary North American suburban expectations of family life.

Iran has a variety of climates, warm and dry, cold and dry, wet and temperate, and the use of traditional Iranian houses in warm and dry climates is very widespread in Iranian cities. These houses, referred to as courtyard houses, act as a consistent building typology, are built in a variety of sizes for different income circumstances, but all share similar characteristics. Rituals, culture, and climate have been the most important aspects of their development, and most are built for extended families. The connection to a captured nature inside the home is a key focus of their design. Such a courtyard, which is a center of domestic activity, encourages this connection, being a place where much household activity happens. Physical circulation around the courtyard from indoors to outdoors ensures that entering the house does not shut out the outside world entirely, which is often the case with traditional Canadian houses. At the same time, the home's residents are unseen and apart from the wider life and people on the street; an emphasis on private life is very central.

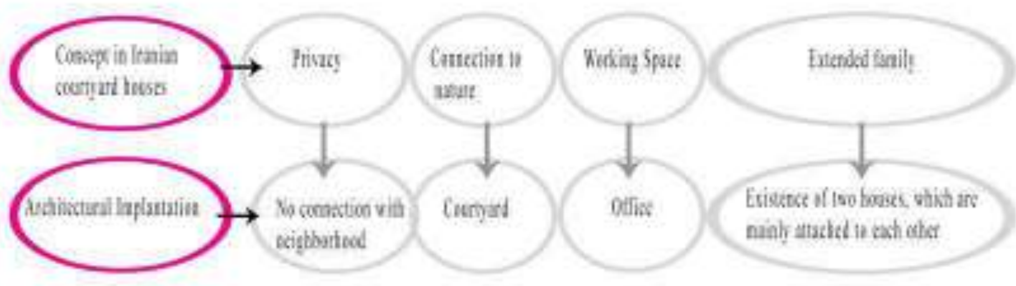

Figure 1: The important concepts in Persian courtyard houses and their appearance in architecture

2.1 The House Case Study Project Envisioning an Iranian Family Home

The scenario of this case study house envisions an Iranian family who has moved to Canada recently. They are going to build their dream house at Bloomington and Yonge Streets in Richmond Hill, which is an area of upper middle class new suburban developments. The cheaper land in this area, in addition to the larger building lots, would enable their builder to include aspects of Iranian design into the house for their extended family. The design goal is to incorporate the values of Iranian families and family homes, like the ones described above, into the new environment. Among other features, since working from home is popular, the house also needs to accommodate a work space. For instance, a young mother of an Iranian family might be a kindergarten teacher, and she would be interested in owning a daycare in her house so she could live at home and work in the same place.

Keeping a large home for an extended family would make the house project model larger than a usual suburban house. It is more like two houses in one. The role of nature is highlighted in these two extended family homes by two courtyards. As a result, this specific design for the imaginary family also shows the physical effects of immigration in a suburban neighborhood. More typically, suburban houses usually consist of a backyard and large windows in the front of the house facing a grassy lawn. In the case study house the backyard is replaced with a courtyard as its open space, and the entrance is the only spot where the family could interact with its neighbors.

3 THE EXAMPLES OF IRANIAN COURTYARD HOUSES

Traditional Iranian courtyard houses are the basis of the house design, and will be adapted in this paper for the suburban neighborhood. Two examples which follow show the use of similar concepts in Iranian courtyard houses. These houses were built in the Qajar dynasty, which ruled Iran between 1785 and 1925. The leaders of this kingdom were a native Turkish family and the examples of courtyard houses illustrated in this paper belong to upper middle class Iranian families of that era. Both homes are still currently being used as family dwellings.

3.1 Gerami House

Gerami house was built in the late Qajar era, out of two different houses for an extended family. Each section has its own central courtyard. These two joined houses obey similar rules and concepts, but they are very different in size and structuring of space. The bigger house belongs to the larger family and the smaller house belongs to a smaller family.

The two courtyards are aligned along a northeast-southwest axis parallel with the street. The circulation throughout the house is based on the two courtyards; in order to go from one space to the other one needs to pass through the courtyard. One can also observe the courtyard from most rooms in the house. The southern courtyard is larger than the northern, and the spaces surrounding it are more substantial since the southern courtyard was built for the larger family.

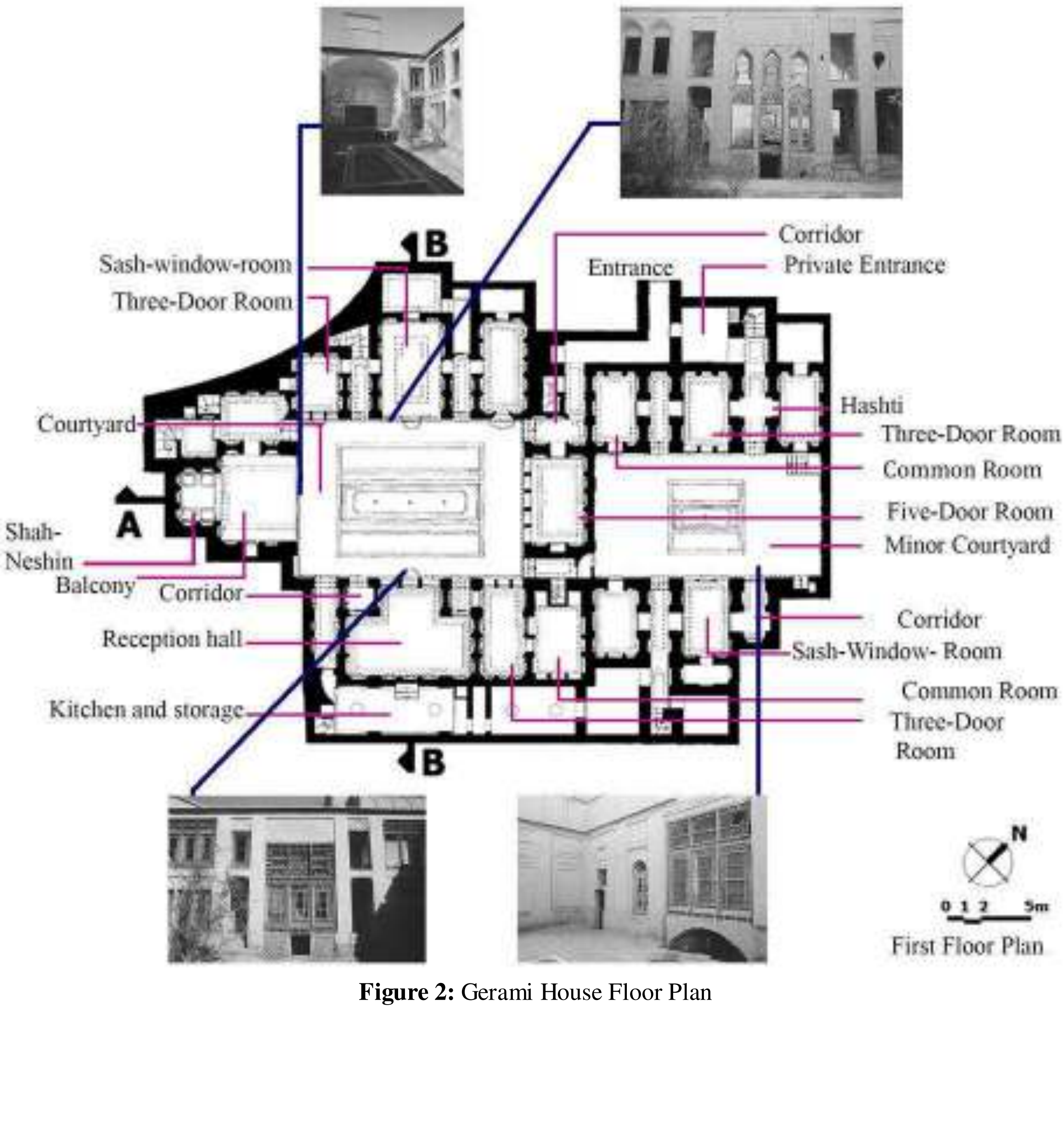

Figure 2: Gerami House Floor Plan

The larger courtyard is surrounded on all four sides by rooms, but the rooms around the smaller courtyard are only on the eastern and western sides. Eastern and western facades of the home are solid walls which are covered with arcades. The arcades not only create shadows in the yard but also give the wall a non-solid appearance. The larger building is two storey and corner areas have higher ceilings and roofs. The smaller courtyard is one storey. The proportions of the courtyard area to the surrounding wall in the two courtyards are almost similar.

The first entrance of the building is used for both the two houses and is followed by the second private entrance for each house. The two courtyards do not have direct views of each other since the two houses act as two individual homes. Both houses share storage and a kitchen, which is located in the eastern part of the overall building. The large balcony on the southern facade is the highlight of the courtyard. The shah-neshin (a sitting area for guests) is located behind a large balcony; this feature is almost similar in every traditional Iranian courtyard house. The Sardab (an underground space in a building) is located under the shah-neshin. During the warm seasons of Kashan (40-50'C), the temperature difference between the Sardab and Courtyard is about10-15'C. The Shah-Neshin is located under the wind catcher (badgir), an Iranian element for natural ventilation [2].

3.2 Tabatabaie House

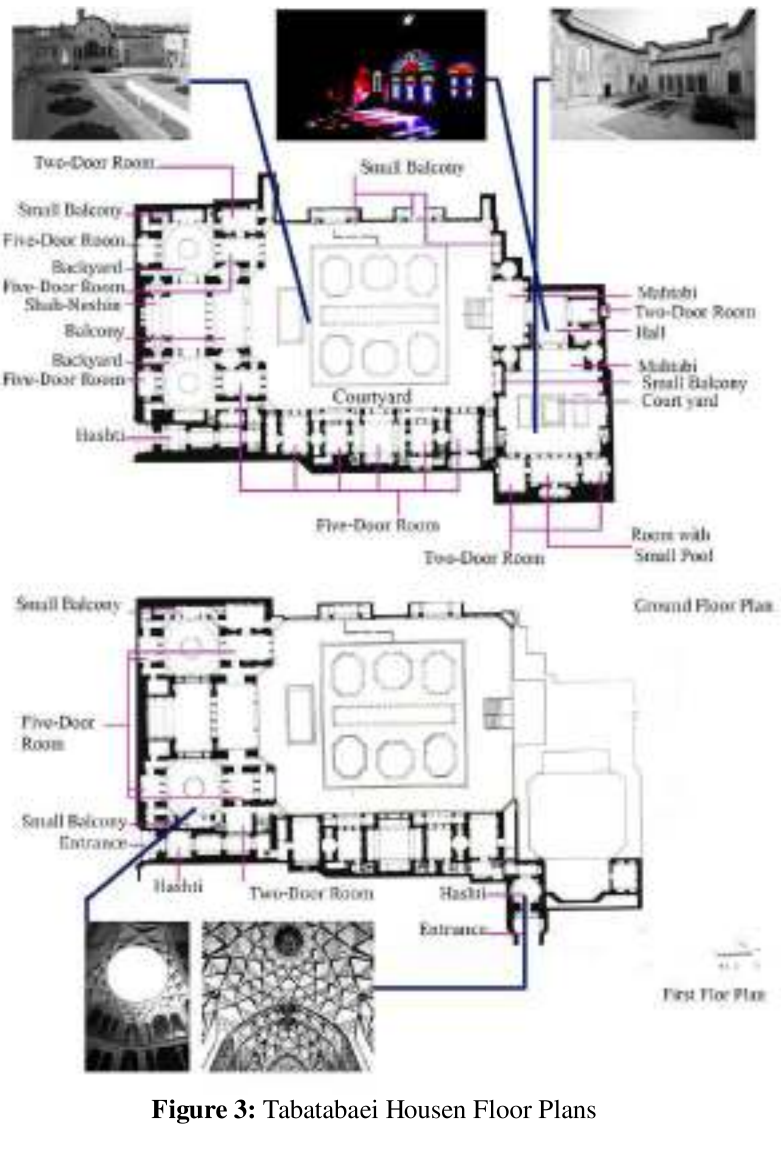

Figure 3: Tabatabaei Housen Floor Plans

This house is a combination of two dwellings to accommodate an extended family, similar to the Gerami house. The southern façade is comprised of a balcony with high ceilings. The higher height of the ceiling accompanied with the semicircular arch makes this facade the most significant elevation. The big hall plus the shah-neshin is behind the main balcony on the southern façade. This hall is located between two smaller yards. In this case, the main hallway has a view of nature from three sides. These smaller yards are surrounded with the two-floor building, both of which are used in winter. The three-door rooms on the second floor open to the smaller yards.

The western part consists of the saloon and three-door rooms. The eastern elevation is symmetrical with the western façade, including the two balconies. Generally the design of this house is based on symmetry. The main entrance is located on the northeast side of the building. The sardab is located in the southern part of the building, in the basement.

4 ADAPTION OF IRANIAN COURTYARD HOUSE TRADITION FOR SUBURBAN HOUSE IN RICHMOND HILL

The aim of the new design is to use the concepts from the two above houses and adapt them for a Richmond Hill suburban house. Iranian traditional houses used in the Richmond Hill case study, the Gerami and Tabatabaei houses in particular, follow similar design rules. The most important room in all these houses is the courtyard, which defines the circulation of traffic. The first step in the design case study then is to design an Iranian courtyard and, as has already been discussed, transform it to the needs of the climate, location and needs of a family life in Richmond Hill. These new developments in Richmond Hill are not only similar in their street-facing facades, like the Canadian homes they replace, but also share similar plans and interior organizations around courtyards. In this way they can move to being a replicable type and not solely a custom home.

A corner building lot has been chosen since it is larger than a typical building lot; the chosen case study site is actually combination of two lots, one corner and one ordinary.

Figure 4: Location of the chosen site in Richmond Hill

4.1 Design Strategy

As noted already, the first characteristic of the Iranian house is a courtyard. The translation from an Iranian typology can be simplified into a newer typology with definite characteristics which in turn can be adapted. Spaces in traditional Iranian houses are categorized into two groups: open spaces and closed spaces. Yards or open spaces in residential areas have diverse functions; one involves cultural and ritual characteristics. The other important function of enclosed central courtyards is to create privacy. The walls block the view of passersby and strangers. The courtyard functions as a private area for family. This important function in the yard suggests that the function of the courtyard is based on cultural phenomena. The courtyards also encourage the relationship between humans and nature.

Figure 5: Design of traditional courtyard house regardless of climate on site conditions

The drawing of the main plans, section, and diagrams shown in Figures 6, show a translation of traditional courtyard house features to a Canadian suburban home with Iranian cultural features. In the Figure 6, the most important space, the courtyard, doubled as in the two precedents, is evident in the proposed house. Circulation in Iranian traditional houses is that in order to go from one space to the other, residents always need go out to courtyard and come back in. Iranian courtyards also maintain both the relationship to nature in the courtyard garden, and then to the people in the home based on such circulation throughout the house. The traditional truly open phenomenon cannot be literally adapted in the Richmond Hill suburban house due to the severe Canadian winter climate, however. The home's courtyard circulation is kept, but instead, in a covered courtyard. The flooring material, which is brown brick, is extended to the inside area in order to highlight this in and out courtyard circulation.

Figure 6: Transformation shown in plan based on circulation around the courtyard

Figure 7: The function of spaces in designed house

Figure 8 : Section 1-1

Figure 9 : External vignette

This vignette shows the visual and programmatic effects of this cultural house on the neighborhood. Although the material of the elevation is similar to adjacent building but this house certainly change the view of neighborhood. The opposite slope of the roof and fewer openings on the exterior facade are the characteristic of this elevation.

5 CONCLUSIONS

This paper suggests the potential of generating a new architecture based on the traditional architecture of immigrants blended with homegrown style architecture. The research focuses on the residential neighborhoods in a suburb of Toronto with high population of Iranian immigrants. It tries to manifest a new typology for the Canadian suburban home, one based on Iranian courtyard houses. The result of this design fusion is a hybrid combination of contemporary and traditional architecture for new developments in Toronto.

One of the major questions in this thesis is how to add Iranian features to Canadian buildings and so represent a new immigrant identity. This new identity is not the repetition of suburban boxes, as pictured in Canadian critiques of suburban uniformity, nor should it be foreign to immigrants who are not Iranian. Instead, the hoped for transformation should use Iranian tradition in a way suggested by Louis Kahn in Isfahan in 1970: “Traditions are as golden dust falling in space. If one but had the possibility of grasping this golden dust, we would possess the powers of anticipation of the future”.

The aim of this project has been to create an urban form in residential areas that reflects cultural values of ethnic groups. It is hoped that repetition of these forms would make those groups feel at home. The formation of these hybrid cultural buildings is based on the concepts and functions of courtyard houses in Iran, resulting in a combination of historical housing traditions with contemporary suburban norms.

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CHAPTER VI

CONSTRUCTION METHODS and MATERIALS
of
NEW DESIGN in HISTORIC ENVIRONMENT

CORRELATION OF SOCIAL AND TECHNOLOGICAL ASPECTS IN DECISION-MAKING PROCESS RELATED TO THE PROTECTION AND ENSURING THE AVAILABILITY OF HISTORICAL MONUMENTS FOR TOURISM

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Keywords: Revitalization of Monuments, Interdependence of Technological and Social Problems

Abstract.

Introduction:
Many of the very significant monuments of material culture are located in areas that are currently away from the major centers of civilization, and are often hard to reach. This has important implications for the conduct of archaeological work, as well as for the construction works related to the protection of monuments from the adverse effects of the weather, and sometimes also from theft or vandalism.

Development:
In the case of the monuments in the vicinity of small, distant villages, all activities associated with them have a very large impact on the local community. On the one hand, they are reason for well-founded pride and consolidate community on the basis of local patriotism. On the other hand, archaeological excavations and protection works allow a large group of residents to find employment, often for many years. At the same time, carrying out any works in remote and difficult terrain is associated with technological and financial difficulties. Only in a few cases of the objects of exceptional importance, it is possible to ensure at every stage access to modern technologies currently used in construction industry (of course this does not apply to technologies related to maintenance of the works of art: paintings, etc.). Far more common are cases where most of the works should be done by using technology and materials available on site.

Remarks and Conclusion:
Sometimes these are – stored in the local memory – old methods having roots as far back as in the period when the protected objects were created, and sometimes – simplified and somewhat "distorted" versions of modern methods. An important aspect of the use of local technologies is also the possibility to provide the inhabitants with additional employment and enable them to contact with modern technologies. Any rational action related to the construction works on such located monuments must take into account the above-mentioned limitations. Linking, already at the design stage, of the proposed technological solutions with the capabilities of the residents of local communities, is an important factor for the success of the revitalization projects.

1 INTRODUCTION

Making available historical buildings for visitors is one of the main objectives (except of research tasks) related to their revitalization. This involves very often carrying out the strengthening and protective works, and also construction of new structural components or even whole new objects.

Strengthening and protective works can be divided into two groups. The first group is associated with securing and local strengthening of construction of the object, in order to ensure the safety of the visitors. The second group of works includes some additions and minor modifications to facilitate access to the building and allowing exposition of its most important parts.

Below is presented a typical problem associated with this type of works on the example of the object originating in the eighth century, located in Old Dongola (ancient Tungul, now el-Ghaddar [1]) north Sudan.

In the building were used two types of floor structures. Above the ground floor are mostly adobe vaults, with a cross section close to parabolic, filled with a similar adobe material. At the upper level and the stairwell – wooden floors are used. There are ceilings made of untreated or partially treated beams filled with pugging of adobe and clay, laid on a mat of reeds. Locally for fillings were used adobe bricks. In the later period of exploitation of the building, wooden beams were also used to repair damaged portions of the vaults, Figure 1, left.

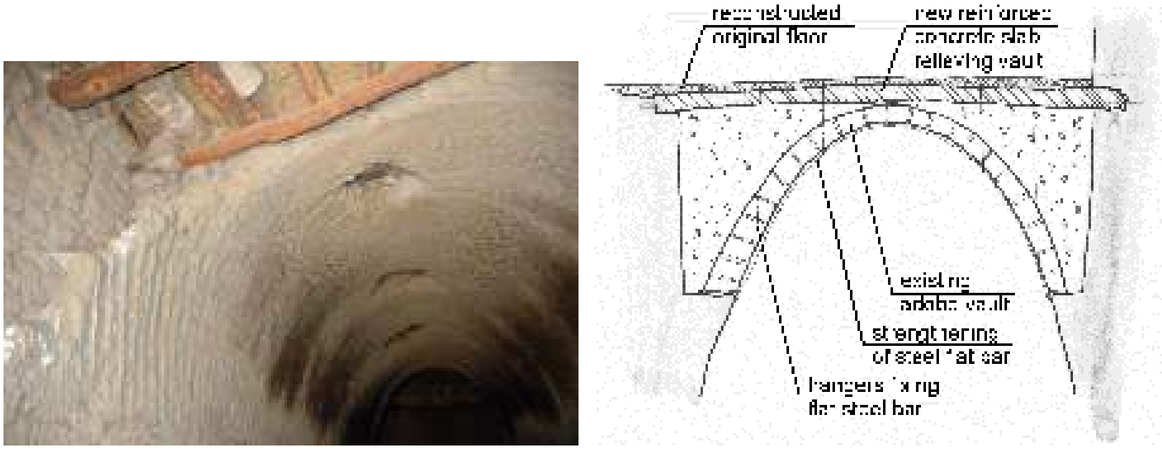

Figure 1: Example of a building that needs to be strengthened before making it available for visitors: left – view of the typical vault over the ground floor; right – cross section through the vault after completing the reinforced concrete slab (working sketch made on-site)

Due to the fact that the ceilings are much destroyed, it is impossible to make them accessible to visitors without adequate securing. As a general solution, both for the vaults and wooden beams floors, it was decided to construct an additional reinforced concrete slab, not connected with existing floors. This slab will be made within the existing pugging layer and will not increase the overall thickness of the floor. On its upper surface will be reconstructed the existing floor. The use of reinforced concrete slab will protect existing structural components of floors by suspending them by steel hangers. In addition, supporting and connecting the slab with the walls of the building will increase the overall rigidity to the horizontal forces and protect against deformation the walls, in which there are no other components with this function, such as rims. The general idea of strengthening the floors is shown on Figure 1, right [2].

2 PROBLEMS WITH THE IMPLEMENTATION OF THE DESIGNED TECHNICAL SOLUTION

Any investment, regardless of location and time, in which it is executed encounters different types of restrictions. They usually arise from the financial resources available, the conditions associated with its location, as well as the current general context – the level of technical development, burden of the construction industry, ambitions of the investor etc. Such restrictions are regular part of every investment process. This also applies to activities related to the monuments, because despite the entire cultural envelope, they are subject to the same rigors technically and economically, like any other business.

However, in the case of monuments, there is an additional aspect that must be taken into account. They are often located in areas where the population does not feel a direct connection with the civilizations whose products are these objects. They are located in their area, but the cultural continuity, and therefore emotional relationship with them – disappeared. At the same time, it often happens that in these communities are preserved in the collective memory, and are used in practice, technologies that are similar or close to those used at the time when the object was created.

The involvement of local communities in the construction work therefore has a number of positive aspects. On the one hand, it is somehow "naturally" to use traditional technology, and it is often a great help in carrying out the work. On the other hand, it allows to embed this work in the of socio-cultural context and gain acceptance for them, which is later transferred to the object which is the subject of works. Not without significance is the fact that on this occasion there is also a gradual transfer of modern knowledge and technology. This is a positive footprint on the area, remaining after the team leading the work.

To achieve this positive effect, however, is crucial to understand the existing restrictions and adopt them as an objective factor that should be considered when planning the works. Local knowledge should be tapped to understand sources of material, technology of working and should be compared with the historic material [3].

In the example cited above technical solution designed to strengthen the building, was confronted – before the commencement of construction works – with the technical capabilities of their execution, during works on another object located in the immediate vicinity of the described one. Presented below are most important problems of this type.

3 LOCAL TRADITIONS AND CUSTOMS – LIMITATIONS AND BENEFITS ARISING FROM THEM

3.1 Limitations in the preparation of bulk materials in situ

Performing masonry and concrete works requires preparation of large quantities of mortar or concrete mix. They must be done in situ, in the immediate vicinity of the object, and used in a relatively short period of time. Local contractors are faced with several problems. The first is the availability of binder, especially cement, which is sometimes quite expensive and not always available. The second problem is water. Its delivery it requires a special transport arrangements – sometimes are used tankers pulled by donkey or camel.

Sometimes happens that water is drawn directly from the river. Another problem is the availability of a certain fraction of the aggregate. Coarser aggregate usually has to be transported from a distance. Yet another problem is the use of mechanical mixers which require a power supply. If it is not available from the network, which is often the case, it is necessary to use additional power generators.

For the preparation of mortar, are often used local soils with a high content of clay and loam, which are suitable as a binder. Mixed with local sand allow making mortar suitable for bricklaying. Moreover, if these soils are located at the construction site, it is possible to combine in a single technological cycle extracting and preparation mortar, Figure 2, left.

Figure 2: Preparation of basic construction materials in situ, without the use of mechanical devices: mortar for bricklaying (left) and concrete (right)

For the preparation of concrete mix, it is necessary to provide aggregate and cement. In both cases, the combination of constituents and preparing of mixture is done manually. The mortar is simply worked in the pit, to which water is added and, after taking up transported directly on the top of the constructed wall, Figure 3. Concrete is produced on a base surface tiled with fired bricks, substituting the mixer. First, a dry blend of constituents is prepared and then is gradually added water, in amount necessary to prepare the required amount of concrete, Figure 2, right.

Figure 3: Bricklaying of walls made of bricks fired in the traditional way, using mortar on base of local loam

With this technology of producing, serious problem is to control the composition of the mix – the quantity and quality of the ingredients. While for less responsible constructions, in particular for walls, this is not critical, in the case of concrete structures such as floor slabs can be decisive.

3.2 Limitations in the availability, use and culture of exploitation of the equipment

As mentioned above, one of the restrictions on the use of equipment and mechanization of works is the problem of availability of electricity on site. This limits the use of both major equipment and small tools. In the latter case the limitation is even greater, because in many situations it may be cost-efficient to use the fuel propelled generators to supply the large equipment such as, for example mixers. However, it becomes a completely unjustified to operate power tools such as drills, hammers, saws, etc.

Figure 4: Replacing unavailable or expensive equipment by homemade devices – simple welder

It overlaps with the problem of the availability of modern equipment, resulting primarily from their cost. In addition, weak technical preparation of the staff causes that more advanced devices that require heavy maintenance, easy fails and – against poor availability of service – are no longer useful. The result is sometimes a complete abandonment of the use of equipment, or replacing it with simple homemade devices. In Figure 4 is presented a primitive welder done in such a way. This device, which is basically a simple transformer, allows welding with use of electrodes having a diameter not exceeding 2.0 mm. It does not always provide adequate merger of melted parts that are to be joined. It is not possible to accurately control the welding current. Also, job security is far from required.

3.3 Lack of tradition of the use of certain solutions, structural schemes, connections and materials

During the works related to securing the sights and making them available to visitors, there is very often necessary to apply solutions that are very different from the original ones. This applies, for example, the roofing of the area with elements of much larger span, in a situation where the internal structure of the object is not preserved and there is necessary to ensure free access to its remains.

Similarly, allowing access to the upper floors of building for larger groups of tourists may cause a much higher load on floor structure, than it was originally, when the building was used in a different way. These actions lead to the necessity of introducing structural solutions that go beyond the ones known to local craftsmen, traditional schemes. In this case they lose their functional reliability and precision, and it is necessary to instruct them and carefully supervise the work performed.

An illustration of this can be roofing of the object, the structure of which originally consisted of domes based on massive brickwork columns. At the moment, within the exterior walls remained only lower parts of the columns. In order to cover the object while leaving the full freedom to carry out research in its interior was designed lightweight roof structure of steel trusses without intermediate supports.

The steel structure is made of locally available RHS profiles that are commonly used to make roofs in small residential buildings. However, they were always used as a simple beam with a relatively small span. Static scheme of truss was new to the contractor, Figure 5. Furthermore, the above mentioned limitations in welding technology have narrowed the possibility of shaping structure. However, with close supervision was possible the proper execution of the construction.


Figure 5: Minor modification leads to a new quality – simple steel components (RHS) used to make the long span truss, instead of straight joists

Another non-standard element associated with the described solution, was the need to protect the steel structure against wind suction, which locally can reach significant values. As the steel structure was very light, it was attached to the exterior walls, which are a kind of ballast balancing wind suction. In order that masonry wall made with loam mortar was able to transfer tensile forces, the cores made of reinforced concrete were inserted into wall, connected with a kind of rims placed in the bottom part of the wall, so that whole its weight provides a counterbalance to the wind suction, Figure 6. Combining in a one structure reinforced concrete and masonry were completely new to the contractor, who initially treated it as a kind of "whim" of the designer. The meaning and usefulness of this approach became clear to him only after the completion of the whole structure.


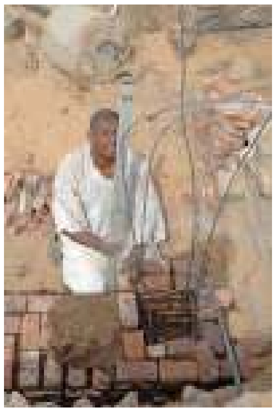

Figure 6: Implementation of a new technology – a combination of masonry and reinforced concrete

It was very interesting to observe how the contractor, working according to the technology new for him, gradually learns and begins to understand it. The final satisfaction of the constructed structure was even greater because its effectiveness has become understood and allowed him to acquire new skills.

3.4 Local solving of local problems

However, the skills of local craftsmen did not always cause limitations. They often have ideas how to easily solve problems that otherwise might require multiple technological treatments. This can be illustrated on the example of execution of simple reinforced concrete elements – footing of the column. Replacement, during preparation of formwork, a very scarce wood by carefully made excavation significantly simplified works and reduced their cost, Figure 7. Similarly, instead of using special coating over the concrete surface protecting before drying out, or frequent spraying water, which is hardly available in the desert, local workers ingeniously used a thick layer of wet sand, retaining the right conditions of curing for a long time, Figure 8.

Figure 7: Saving of timber for formworks during construction of reinforced concrete structures

Figure 8: Creative local solutions applied to modern technologies: care of the maturing concrete – cover of the surface with a layer of wet sand

4 PROBLEMS OF INFORMATION EXCHANGE IN THE INVESTMENT PROCESS

4.1 The investment process as the process of generation and exchange of information

When a man, sheltering from the weather conditions went from the initial phase of search for a refuge in natural places and the construction of primitive huts, to the phase of construction of objects that can be called (according to our present terminology) houses – construction as one of the important areas of human activity was born. Then appeared specialized craftsmen engaged in building not only for their own purposes, but primarily for the needs of others. Almost immediately appeared the problem which we would call today “the modeling of building objects”.

Every building object emerges first as an abstract idea related to the needs of investor. This idea is translated onto architectural language and converted to the architectural concept. The initial concept is developed up to the stage of detailed design, which must be then communicated to the contactor, craftsmen etc., so that they could build an object corresponding to the contract. Information is produced and exchanged at every stage of the investment process.

The amount of information and number of connections between the participants in the process, for its exchange increases rapidly with the transition to the successive phases of investment. Since the exchanged information covers a variety of specialized fields and are produced and stored in various forms, their exchange requires the use of appropriate tools, such as classification, coding, graphic conventions, textual descriptions, etc. [4], Figure 9. The designer must have the ability to save his idea in such a way that it can be transmitted to, and then received and properly understood by the recipient i.e. the investor, contractor and craftsman. The ability to exchange information is a precondition for design and construction of a building.

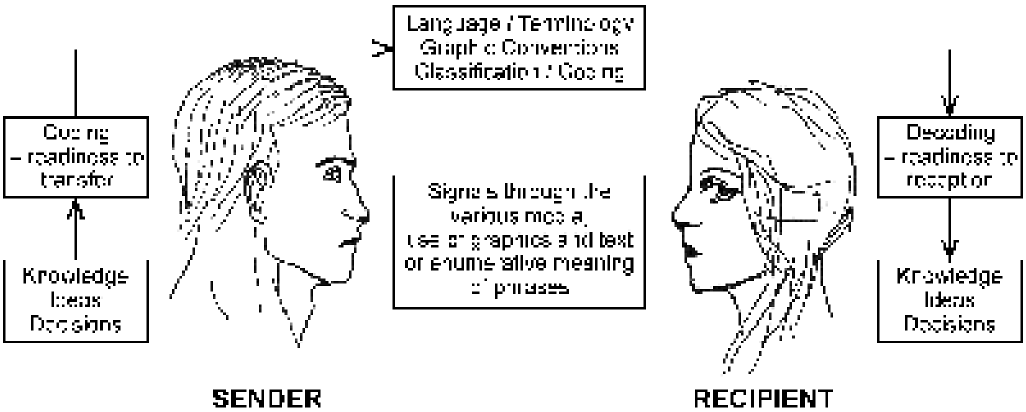

Figure 9: Exchange of information in the investment process according to ISO Report [5]

As long as the activity concerned common, well-known and accepted technologies and solutions, "model" of the building could be very simple. A simple residential building could be described simply by the amount of chambers. In the case of the palace and sacred buildings, more complex descriptions were used, including drawings.

4.2 Exchange of information in case of significant differences in the technology used

Diagram shown in Figure 9 relates primarily to a situation where information is exchanged between the agents involved in the various areas, for example: structural engineer and architect, or operating in various stages of the investment process, eg. between designer and craftsman. However, all the tools and resources for the exchange: language, terminology, standards, graphic conventions etc. refer to the knowledge derived from a common technological, civilization and cultural base.

The issue greatly complicates when the transfer takes place between the participants, who cannot refer to the common base. If the sender of information refers to technologies that are unknown to the recipient, the transfer of information in a standard way fails. The same is true with the media. If the graphic conventions, terminology and specialized language used by the sender are alien to the recipient, the transfer of information will not occur. This problem often occurs in the situations described above. Going beyond the locally accepted and applied knowledge and technology can lead to difficulties in communication such that any transfer of information becomes impossible. Accordingly, as mentioned above, becomes impossible execution of the works.

It is important to find the greatest extent possible, a common database, which can be appealed. The balance between advantages that can be taken from the technology available locally, and what is necessary to be taken from the outside becomes crucial in this context, as a prerequisite for any cooperation.

5 SOCIAL IMPACT OF THE COMMUNICATION IN THE CONSTRUCTION PROCESS

Small local communities, especially in areas distant from the major centers of civilization, are often very closed systems, hostile to changes coming from the outside. The very fact of executing works within their territory of works related to objects, with whom they do not identify themselves, are interpreted as a strong interference with their way of life. Especially, if it involves the expected influx of tourists and associated service infrastructure.

The inclusion of these communities in the execution of the construction works is therefore important not only because of the need to find a workforce. Equally, if not more important is to build proper relations between local communities and specialists arriving from the outside, as well as a positive relation to the revitalized historic sites.

Working together, of course, helps in this regard, but it can be a source of further difficulties. If there are problems in the exchange of information at the technical level, there is a temptation to avoid them by minimizing the participation of local contractors and importing materials, equipment and employees from outside.

This approach can destroy all the social benefits of the common work. On the other hand, too optimistic, ill-considered involving of local technology and excessive confidence in them can be the cause of a technical failure of the project, and even – in extreme cases – construction disaster. Balancing is in this respect a very important and difficult, requiring a large practical experience.

As described at the beginning of this paper, on the example of the building which is prepared to be available for tourists, such a problem emerged in the analysis of technical solutions of strengthening of the floors. Adopted initial solution assumed a monolithic in-situ casted reinforced concrete slab, as shown in Figure 1.

However, before construction works on the building has started, during the execution of concrete works related to other, simpler elements, it turned out that getting quality and accuracy required to implement the original project solution may not be possible. The final result the one hand may not provide security to visitors, on the other hand, may excessively interfere with the existing substance of the building. Therefore, currently analysis to find alternative solutions is carried out. Considered is the possibility of use of on-site prefabricated elements and their manual assembly or use a cloth soaked in a dry mixture of concrete – the Concrete Canvas system. In both alternative variants it is assumed that the contractor is a local company.

6 CONCLUSIONS

The above observations allow the following conclusions:

- Construction activities associated with the revitalization of monuments, especially in areas distant from the centers of civilization has several important aspects of the interaction with the local community.
- In purely technical terms should be taken into account limitations associated with the local availability of existing technologies and handicraft traditions.
- Cooperation in such projects is frequently a kind of the transfer of technology, often on both sides.
- Aspect of the exchange of information related to the description (model) of the planned work is extremely important and is a potential source of threats to proper communication.

- Social footprint of technical cooperation is essential for the local acceptance and support of all construction activities.
- Public acceptance is also associated with the formation of local patriotism, pride and attention to possessed monuments.

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CONTEMPORARY TECHNIQUES VS AUTHENTICITY - STRENTHENING OF THE OLD QUAY WALL OF SUOMENLINNA, FINLAND

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Keywords: Historical Structure, Renovation, Drainage System, Heating Cables, Preservation

Abstract.

Introduction:
Suomenlinna (built in 1748) is a sea fortress situated on six islands at the entrance to Helsinki harbor, Finland. In 1991, Suomenlinna was added to the UNESCO World Heritage list as an outstanding example of a type of building that illustrates a significant state in human history.
The dry dock is located at the heart of the fortress. With galley basin, lock gates and paternoster device, it was the state of the art technology in the 18th century. A section of approximately 9 x 11 m of the corner wall deteriorated from exposure to seawater and frost.

Developments:
The process of restoration commenced in 2012 by stabilizing the damaged gravity wall. The structure then was tieback anchored and steel reinforcing bars were attached before a new concrete wall was placed. A new drainage system was installed; fitted with heating cables to secure its functionality during prolonged sub-zero conditions.
The heated drainage installation elicited a discussion over a fine line between restoration and preservation on one end, and renovation and functionality on the other end. The opponents argued that such addition is a major interference of the established restoration procedures for structures with heritage value. The proponents defended the idea emphasizing that the benefits of the heated drainage system prevail over the authenticity since they undoubtedly extend the structure's lifespan.

Remarks and Conclusion:
The strengthening options were found to be appropriate to achieve the desired objective and at the same time being minimal invasive, quick and discreet. In addition, the selected method has proven effective in keeping the wall close to its original condition for many years to come.

1 INTRODUCTION

Suomenlinna (Sveaborg) is a sea fortress which was built on a group of islands at the entrance to Helsinki harbor in 1748. Its architecture and landscape have been shaped by several historical events, and the fortress has served to defend three different sovereign states over the years: the Kingdom of Sweden, the Russian Empire and, most recently, the Republic of Finland [1].

The fortification became a strategic military shipyard with one of the biggest dry docks in the world, comparable to the fortress at Gibraltar. Suomenlinna was added to the UNESCO World Heritage List in 1991 on the grounds of I meeting criterion (iv), which classified the fortress as an outstanding example of a type of building or architectural ensemble that illustrates a significant state in human history. These days, Suomenlinna is a popular tourist destination (Figure 1).

1.1 Intactness and authenticity

Suomenlinna consists of a series of defensive and utility buildings in a way that the architecture and functionality of the fortress blends with the surrounding landscape. Most of the fortifications and utility buildings from both the Swedish and Russian eras have been well preserved. The fortress has only a few buildings from the Finnish era, and they all retain their own distinctive identity.

The fortifications from different periods, the surrounding environment and the various buildings from different eras make Suomenlinna an ensemble with its own characteristics preserved with respect to the architecture, building materials, and building methods. Traditional construction methods are favored to ensure the preservation of the area, and the open spaces and areas of the site are utilized in a manner that respects the cultural and historical values of Suomenlinna. The possibility of a sharp rise in sea levels owing to climate change constitutes a threat to the site, as it would accelerate the erosion of coastal structures. Similarly, increased rainfall causes damage to wooden and stone structures. The increase in visitors has also caused sandbanks to erode during the summer. Although the affected zone constitutes a relatively small part of the site´s total area, the erosion is managed with reports and by restricting visitors` access to the vulnerable area.

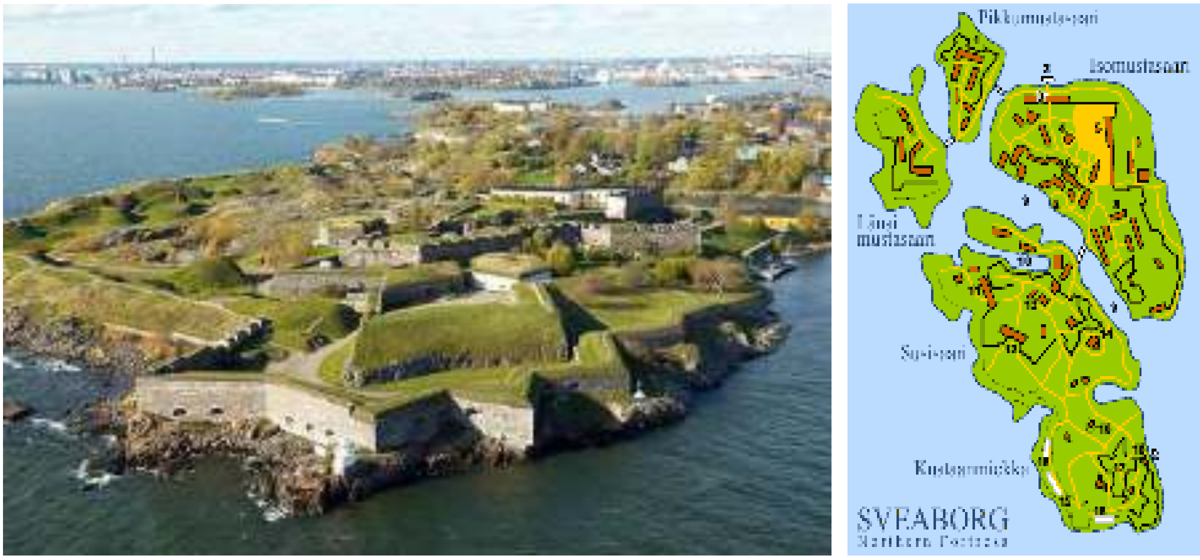

Figure 1: Suomenlinna fortress - photo and map.

1.2 Management plan for Suomenlinna

The Management Plan of the Suomenlinna World Heritage Site guides the preservation and development of the site. It consists of several levels of priority for putting the long-term goals into practice. The basic principle of the plan for the use of Suomenlinna is that restoration and reconstruction are to be carried out taking both antiquarian and architectural considerations into account. The top priority embraces the idea crystallizing the conservation of the World Heritage Site. It is a clear vision of the Suomenlinna of the future which is shared by all. The actual preservation, restoring and maintaining of the fortress is the responsibility of the Governing body of Suomenlinna that has been undertaking repairs on the fortress for three decades.

2 THE DRY DOCK BACKGROUND AND DESCRIPTION

The dry dock is located at the heart of the fortress, on the north side of Susisaari island.
The construction of the dry dock began in 1750. With galley basin, lock gates and paternoster device, it was the state of the art in the 18th century technology.
Since Finland´s independence (1917), the dock has had several occupants. The State Aircraft Factory used the repairs workshop for assembling airplanes in the 1920s. Later, the dock was taken over by the State Shipyard and was converted into a submarine base. After the Second World War, some of the ships required for Finland´s war reparations were built there.

Today, the dock area and its buildings are leased to a commercial repair dock and a private association that uses the large dry dock as winter storage and repair facility for old wooden sailboats (Figure 2).

Figure 2: Dry dock of Suomenlinna and the strengthened corner of the floating door.

3 MANDATE AND SCOPE OF WORK

The mandate of KAREG Consulting Engineers was for the design-build and project management of strengthening of the old quay wall of Suomenlinna.

The phases of the old quay wall strengthening, in particular drilling, injection, anchoring and drainage system installation was undertaken by contractors, sub-contractors and subtrades under the supervision of the author. The project of strengthening of the old quay wall was undertaken during summer months. First phase started in the summer of 2011 and was halted just before winter of 2011. In the spring of 2012 the construction work resumed and the project was finalized in September 2012.

4 STRENGTHENING OF THE OLD QUAY WALL

The dry dock has been systematically modified and refurbished over the time, and consists of structures from many periods. It has also been enlarged and deepened by blasting. The wall face is composed mostly of concrete and partly of chiseled stones. Behind the wall face one finds a gravity wall made of masonry debris from the building site, containing mostly hard rocks, bricks, as well as lime mortar. The height of the dry dock basin walls varies depending on the elevation of the base rock. The bottom level is about – 8.0 compared to sea level MW_{2011} (Figure 3).

The process of restoration and strengthening of the quay wall at Suomenlinna was a complex and comprehensive project which required throughout planning, designing and attentive approach during all stages of the workflow. It entailed, but was not limited to supporting corner of the floating door stabilization, drainage system and heating cables design & installation, as well as a new concrete wall installation.

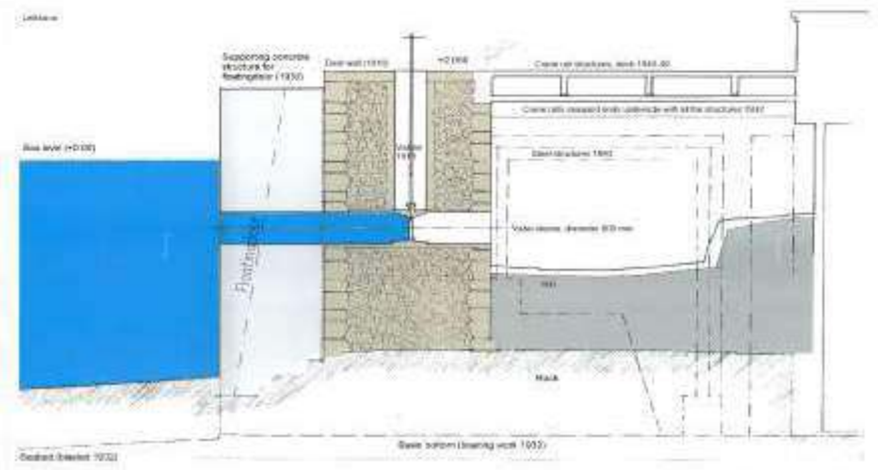

Figure 3: Supporting corner of the floating door. Section. Construction phases and periods.

4.1 Options for strengthening - concepts and methods

Initially, there were two premeditated concepts for strengthening of the wall. First was based on the fact that the basin is filled with water which would mean that the project would be executed underwater by divers. The other approach presumed that the basin was emptied and the work was carried out in the dry dock. Both concepts have significant advantages, but also drawbacks.

An important advantage of the underwater approach is that there is no risk of water pressure from behind the wall. The disadvantage is that the quality of work, in particular exactness and correctness could be significantly compromised under such conditions and circumstances. Another issue would arise from the fact that there was continuous vessel traffic and ships were coming in and out of the dock. It would be impossible, or extremely expensive, to stop the traffic as the shipyard operates as a private company.

The dry dock concept had major advantages in terms of cost-effectiveness and time-management. It also offered essential flexibility as the dock could be filled with water in 8 - 12 hours for incoming vessels and emptied between 8 – 16 hours in order to resume construction work. The shortcoming was to accommodate incoming traffic of vessels which required a great deal of flexibility, scheduling and coordination of construction work with the vessel transit which was at times unforeseen. Decidedly, the benefits and advantages of the dry dock prevailed.

5 STABILIZATION OF SUPPORTING CORNER OF THE FLOATING DOOR

5.1 Temporary basin wall stabilization

The supporting corner of the floating door at the dry dock was made in 1932. Over the years, a section of approximately 4 m (width) by 11 m (height) of the corner of the concrete basin wall supporting the floating door had deteriorated from exposure to seawater and frost damage and was in a poor state of repair. Further damage and disintegration of the structure was caused by water leakage through the wall at an increasing rate despite an attempt to recondition it in 2009.

The wall of the supporting corner was vulnerable with a high rate of dimensional instability. As the test in-situ confirmed, the concrete wall was in an excessive level of permeability which greatly impacted overall strength and stiffness of the structure (Figure 4).

Figure 4: Dimensions of the supporting structure (wall) of the floating door.

The process of restoration of temporary stabilization of the damaged gravity wall was initiated using two vertical grouting steel pipes (114.3 x 5 mm) with 120 holes per meter, ϕ =10 mm, driven 2.0 m deep into bedrock, drilled and installed on the level +2.05 m. The penetration into the bedrock was essential for the structural stability of the wall.

5.2 Permanent wall strengthening using titan anchors

Having had the old corner stabilized, and water from the basin pumped out, the structure could be then tieback anchored. In order to cease and prevent supplementary water leakage from the structure, the old, traditional method of timber wedges was employed (Figure 5).

Figure 5: Practical application of timber wedges.

The anchors design installation was based on the hydraulic pressure of + 2.0 m, water level: max = + 1.45 which is equal with the level of the supporting corner.

The Titan anchors 40/16 Combi-coat were drilled through the existing structure to the depth of 3 m into the bedrock using rock crown drill bit of ϕ =90 mm with centralizing spaces 88 mm [3]. The reason for the large crown drill bit was that the denoted location of the bed-rock was based on expert assessment using available data, therefore there was a slight, but potential probability that the anchors could have been as well bonded in the old, underwater structure.

Figure 6: Titan rock anchors installed.

There were twelve (12) Titan anchors installed with spacing of 1.35 m (horizontally) and 2.0 m (vertically) to secure optimal anchor performance (Figure 6). The anchor inclination angle was between 10º – 20º. Because of the continuous water leakage, the two upmost holes had to be Purgel-injected in order to break off the water flow. The corresponding anchors were injected in a higher inclination angle using Masterflow 928 as a grouting aggregate. All other anchors were injected using standard Portland cement-based grout. The anchors also had a function of the tension bars and they were not post-tensioned. The behavior of the wall and anchors was closely monitored for safety reasons.

6 DRAINAGE AND HEATING SYSTEM INSTALLATION

The process of drainage installation, and in particular, heating cables placement and their positioning elicited a discussion over a fine line between restoration and preservation on one end, and renovation and proper functionality of the drainage system on the other end. The op-ponents of the idea argued that such addition is a major interference of the established restora-tion procedures for structures with heritage value. The proponents, on the other hand, defended the idea emphasizing that the benefits of heated drainage system prevail over the authenticity since they would undoubtedly extend lifespan of the structure.

The supporting corner for the floating door is usually exposed to seawater during winter time. Almost every year, the sea is ice covered to a thickness of approximately 40 cm, with the top of the ice at the level 0.00. From October till the end of April the dock functions as a dry dock. During those months the temperature can drop to -20 ºC. As leaking water from the old wall freezes, it causes damage to the structure mechanically and by enlargement. Water volume expands roughly 10% when freezing. To avoid further damage by frost between the new structure and the face of old wall, vertical drains were installed prior to the pouring the concrete for the new wall.

Several market brands were available. One of them was Enkadrain 10D with a continuous system-like mesh with thickness of 10 mm. It required a straight bottom and therefore it could not be used in this case because of the irregular face of the old wall. Another option was to use separate flexible PVC drain pipes. One principle advantage was that the pipes could be installed individually where needed and shaped following the irregular contours of the wall. For this advantage the PVC drain pipes DN 50 by Uponor infra were selected [4].

Furthermore, the well-known "drainage in shotcrete method" was used. One of the benefits was that when used outdoors in cold climate it is relatively easy to insulate the pipes to make sure that they remain undisturbed while pouring, and don't get clogged in the process. The insulation protects the pipes from the warm-cold cycles typical at the seaside in Finland. It was also possible to maintain the pipes during pouring of the new wall by clearing them with water. A drawback of the method is that it requires attention in situ by the engineer for selecting appropriate routes for the pipes (Figure 7).

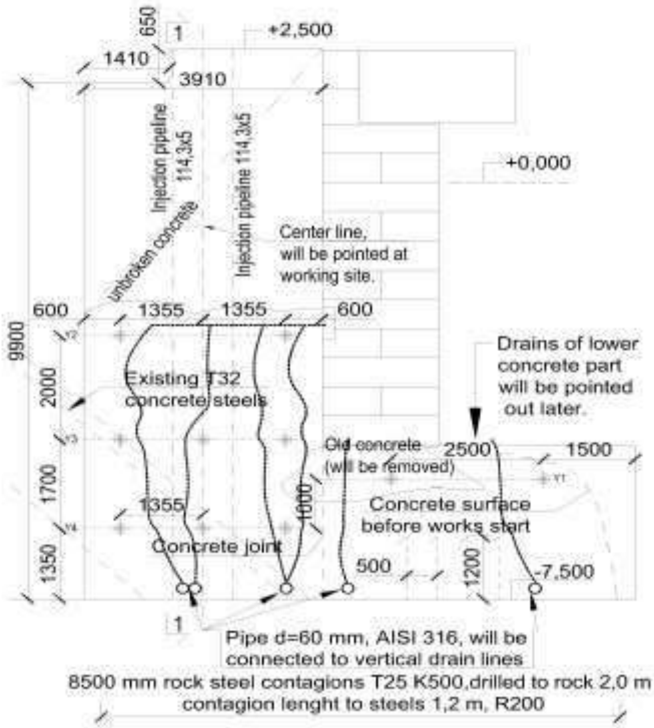

Figure 7: Design drawing. Vertical drainage pipes. Stainless steel pipes for drainage.

6.1 Drainage pipes design and installation

Location of the drain pipes was determined by observing leakage through the old wall and establishing routes for them according to the irregular contours of the wall. Horizontal water collection pipes acting as weep holes were connected to these vertical ones, carrying the water outwards to the bottom of the deck. When designing the strengthening structure of reinforced concrete it was obvious to take care of seepage flow. The engineers experience is particularly valuable in this kind of case, and the design was realized in situ by the first author.

The in situ designed system on the high part of the wall consisted of two single, and one double-pipe vertical routes (4 in all), with lengths varying between 7 and 8 m. They were installed to near vertical position, with exception owing to the old wall's irregular face.

The vertical drainage pipes are of flexible PVC-plastic pipes, applying the conventional so-called "drainage in shotcrete" method tailored for this work including drilled acid resistant threaded rods M10, drainage pipes, polythene board of 10 mm as insulation, hot dipped mesh 3.4 x 100 steel 220 (Figure 10). The PVC pipes DN50 have an opening area between 30...50 cm²/m (lengths between 4...25 mm and widths 2.2...2.7 mm) [5].

The four nearly vertically installed PVC drain pipes of the high part of the wall are connected to three horizontal steel drain pipes at the bottom. These horizontal pipes (in all 5 pcs) are made of acid resistant steel, ϕ 60 mm. The inclination of these pipes is 5 % towards the deck.

Figure 10: Drainage pipes installed and covered by “drainage in shotcrete method”.

Applying the formula of Bernoulli, it was possible to estimate that the amount of water flowing from the vertical drain pipe to the inclined steel pipe was admissible.

$$v_1 = (2gh)^{0.5} \leq v_2 \tag{1}$$

where: v_1 = velocity of water of the drain pipe in m/s, h = height of water in drain pipe, g = gravity, v_2 = velocity of water of inclined steel pipe in m/s.

According to Finnish Regulations and Guidelines D1 (2007) “Construction of water and sewer facilities” is v_1= 0.7 m/s and v_2=1.1 m/s, $v_1 < v_2$ [6].

6.2 Heating cables installation

The drainage system was fitted with heating cables to ensure its operation during winter as frozen water would expand its volume and cause damage. The heating system consists in Devi-Icequard-18 readymade cables 13.1 x 6 mm² with the heating efficiency of 18 w/m in temperature of 0º C and the heating efficiency about 36w/m inside the ice [7]. The district sockets were chosen according to international standard IP-67 and are a model GARO UE11, which can submerged temporarily under seawater inside the dock when a ship is incoming or leaving the dock [8]. When a repaired ship leaves the dock there is the possibility that floating debris such as wood pieces floats against the plastic sockets and damage them. The author found advisable to enclose the sockets in an acid resistant steel box designed to that effect.

7 NEW CONCRETE WALL INSTALLATION

Concrete reinforcement consisted of vertical high-bond reinforcement bars ϕ 20 mm, spaced in 160 mm intervals and horizontal bars ϕ 16 mm spaced in 100 mm intervals. Following proper positioning and securing, the concrete reinforcement bars were cut to desired length and flexed accordingly.

The used steel stress value in Serviceability limit state (SLS) for maximum bar size ϕ 20 mm was 210 MPa and less than 240 MPa. The max bar spacing was 160 mm; i.e. below admissible 200 mm, according to Eurocode 2 [9]. This means no special crack prediction was required.

Because of lack of continuity and so-called “togetherness” of the wall, and also due to its heritage value, it was not suitable to use standard, double-sided formwork. The only alternative was to apply ready-made single-sided type of formwork. It was furnished with Trio and SB2, manufactured by the company Peri Ltd [10]. This system enabled to have the wall face leaning inwards at the angle of the original structure (between 3º – 4º).

The panels of the formwork were anchored against sliding and tensioned by Dywidag bars of ϕ = 20 mm into the bedrock up to 3 m deep, as opposed to the conventional horizontal anchor system. This method was chosen to guarantee the least-invasive work approach to preserve the structure to the greatest extent possible (Figure 11).

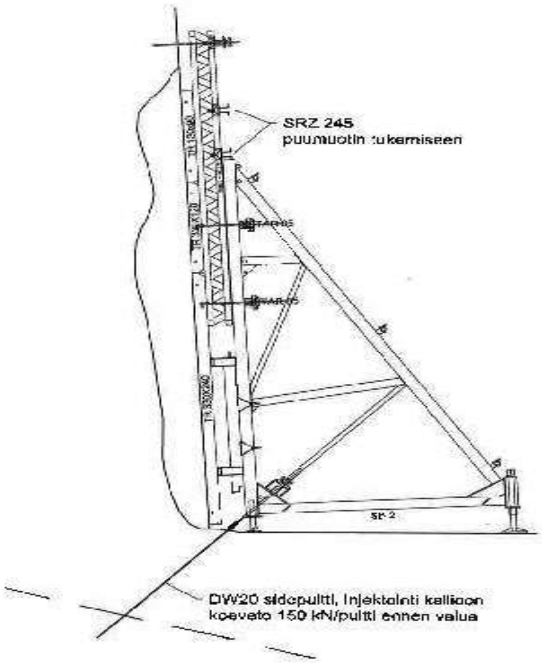

Figure 11: Section of formwork. Dywidag ϕ 20 anchor bars for stabilizing formwork to rock.

In addition, the selected formwork lining imitated the pattern of the original concrete structure so that the process of restoration would fully comply with the preservation principles also from the aesthetic point of view.

The concrete strength was C 40/50. In addition, it had to meet the following exposure requirements: XC4 (wet and dry changes), XS3 (seawater environment with frost).

Transportation and delivery of concrete mass to the side was arranged by a local ferry carrier. Specific admixtures for water reducing and for retarding concrete set were added during transportation to the site.

8 CONCLUSIONS

- The strengthening scheme presented is an economic and aesthetic solution to the refurbishment, restoration and preservation of understrength and unstable wall of the dry dock of Suomenlinna.
- The use of the selected strengthening option and technique for structural intervention of the wall of the dry dock was found to be an appropriate technique to achieve the desired objective and at the same time being minimal invasive, quick and discreet when compared to conventional strengthening techniques. In addition, the selected method has proven effective in keeping the wall in as close to its original condition as possible for many years to come.
- Our work is a reflection of the respect we have for heritage structures and the magnificent work of the military engineers, masons and craftsmen who have gone before. We preserve their legacy by following the established restoration procedures and lending our experience to the collaborative process that is critical to heritage conservation.

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RESTORATION OF THE CHURCHES OF OURO PRETO, MG, BRAZIL

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Keywords: Conservancy, Urban, Cultural, Heritage

Abstract.

Introduction:
Ouro Preto is one of the most important and symbolic cities in Brazilian history and culture. The city was declared a National Monument in 1933, protected by Instituto do Patrimônio Histórico e Artístico Nacional – IPHAN (National Historic and Artistic Heritage Institute) in 1938, and it was the first Brazilian city declared as Mankind's Cultural Heritage by Unesco, in1980. Ouro Preto, as well as other "gold villages" in Minas Gerais, has a peculiar formation, not abiding by radial or nuclear urban organizations that were traditional in Colonial Brazil. Its organic and linear configuration has anticipated the urban development, nowadays known as conurbation, i.e., the formation of a city through the connection of many close urban centers.

Developments:
This article aims to analyze the result of restoration interventions in three Churches that have a special meaning for the city, which are the Church of Santa Efigênia, the Chapels of Bom Jesus das Flores do Taquaral and São José – these monuments were protected by IPHAN on 8th September 1939. An architectural reading of each Churche will be made, examining the material and building systems used in their constructions; their meanings for the city and the heritage designation process, the surroundings in various periods, and the physical, functional and visual relationships with the city. Regarding the recent restoration works, the following will be examined: causes of deterioration, diagnosis and state of conservation, interventions that have taken place over the years. It also will examine the intervention, methodology and the criteria, choices used on both traditional and modern materials and techniques.

Remarks and Conclusion:
In the conclusion the interventions undertaken will be analyzed in the light of modern principles of preservation of cultural heritage, mainly the transformation of the historic environments of the city, caused by the modern and irregular occupation.

1 INTRODUCTION

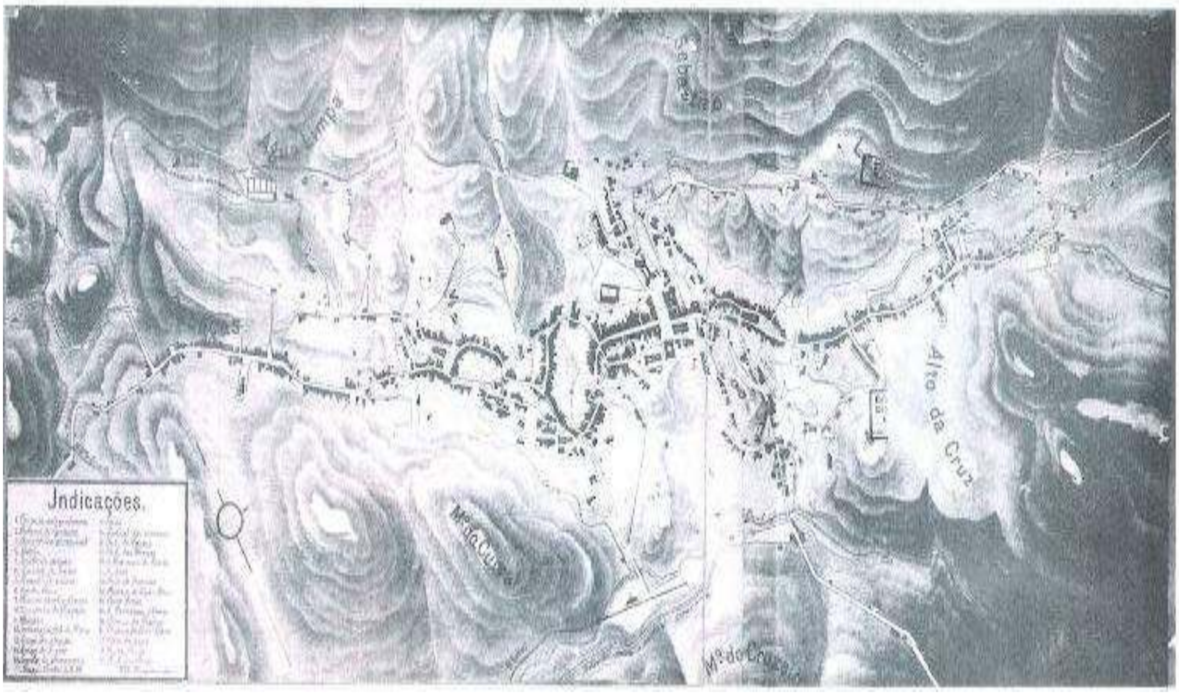

Figure 1: Map of Ouro Preto – 1888. Collection, National Library of Rio de Janeiro.

The Chapel of Bom Jesus das Flores do Taquaral is located in the district that carries its name and belongs to the Parish of Antonio Dias. A primitive mud-and-stud chapel existed on the site; according to Canon Raimundo Trindade, the stone chapel was built by provision of 28th October 1748 by will of the local inhabitants and dedicated to Nossa Senhora do Pilar; in 1855 it was changed to Senhor Bom Jesus das Flores do Taquaral.

The chapel's façade is plain and gracious, but there is a great landscape value as it contributes for a bucolic aspect of the site, especially due to the two interesting bell-gables instead of towers. There is a flat atrium, a stone wall and an iron gate. The frontispiece includes two low-side windows at the choir's level with wooden balusters as railings. On each side of the façade, on the vertical line of the quoins, there is a small bell-gable with semicircular arch openings. The roof is crowned by a white cross. The masonry portal frames a beautifully worked paneled door; above the portal there is an ornate with a semicircular frame and a stucco buckler. On the gable, a masonry *oeil-de-boeuf* glazed in the inner side. The sacristy has a side entrance with a paneled door. The chancel and the sacristy have each a roof that is lower and independent from the main roof.

The interior of the Chapel is simple; the high-altar retable, under the invocation of Senhor Bom Jesus, is quite plain, with a segmental arch, curtains and volutes. There are two masonry carved fonts and a small soap-stone font in the chancel. The pulpit floor is in masonry and the balcony is in wood. The *oeil-de-boeuf* is cruciform. The opening frames are in masonry. The collateral altars, under the invocation of Nossa Senhora das Dores on the Gospel side, and Santo Antônio on the Epistle side, are more elaborate with stylized canopies supported by columns and consoles. The paintings on these collateral altars demonstrate a strong Renaissance influence. On the ceiling of the high-chapel there is a painting representing Christ Crucified and on the nave ceiling a painting represents Nossa Senhora and Menino Jesus (Our Lady and Child Jesus) with Baroque decoration. The altar dedicated to Nossa Senhora das Dores presents simple volutes, niches and estrades; the altar for Santo Antônio has estrades,

Figures 2, 3: The Chapel of Bom Jesus das Flores do Taquaral: in the first half of 20th century (left) and in 2015. Photo by Luiz Fontana IFAC-UFOP archives (left) and photo by Benedito Tadeu de Oliveira.

niches, camarins with golden pedestals, and antique paintings. The chancel-arch is in masonry surmounted by a wooden border.

The Chapel of São José (former Imperial Chapel) is located on an artificial plateau structured by stone retaining-wall, which was later strengthened with reinforced concrete. The first records of the Irmandade do Patriarca São José dos Bem-Casados (*Irmandade* is a religious association of laymen and laywomen who gather to promote the cult to a saint) dates back to 1725, when it was created according to Canon Trindade. The meetings took place at the Matriz do Pilar (Parish Church of Pilar) until the first chapel was built by provision of Frei Antônio de Guadalupe, Bishop of Rio de Janeiro, in 1726. The evolutive process of the Chapel of São José was similar to the majority of chapels and churches of that time: a primitive chapel was followed by the construction of a definite chapel. It is possible that, as in other temples, the primitive chapel was kept until the works of the nave of the definite chapel were finished.

The project of the second chapel is attributed to Francisco Branco de Barros Barrigua, who signed a receipt for it on 20th December 1746. The works begun in 1753 and ended in 1759, according to receipts of José Pereira dos Santos, who built it. The chapel's blessing ceremony by Reverend Dr. Teodoro Ferreira Jácome took place in March 1761. The construction works of the chancel and the sacristy, undertaken by Antônio Rodrigues Falcato, begun in 1760 and finished in 1764. The roof was built between 1756 and 1766 by Manuel Rodrigues Graça, who later made the doors and windows. In 1750 Leandro Soares made the tombstones near the presbytery and in 1773 José Rodrigues da Silva made the tombstones in the nave. In the same year Antônio Gomes Barritos set the nave's cancellus, which was made by Francisco Alvares de Lima. The wooden floor was laid by Leandro Soares Carvalho and José Rodrigues de Sousa between 1769 and 1762. The project of the high-altar's retable was commissioned to Antônio Francisco Lisboa, known as *O Aleijadinho* (the 'little cripple'), as stated on the artist's receipt to the *irmandade*, dated 20th July 1773. The carved work was made by Lourenço Roiz de Sousa between 1775 and 1781. The decorative painting on the ceiling depicting Saint Joseph's Marriage was made by Manuel Ribeiro Rosa between 1779 and 1783. At the presbytery there are four mural paintings depicting the Life of David; they were made between 1779 and 1783 by Manuel Ribeiro Rosa. There is a receipt of Francisco Xavier Gonçalves dated 1782 referring to the painting on the sacristy's ceiling. There is no register regarding the

Figures 4, 5: The Chapel of São José: in the first half of 20th century (left) and in 2015.
Photo by Luiz Fontana IFAC-UFOP archives (left) and photo by Benedito Tadeu de Oliveira.

side-altars that, according to Diogo de Vasconcelos' hypothesis, where brought from other chapels. The interlaced dolphins that adorn the sacristy's fountains were made by José Francisco in 1795. Documents of the *irmandade* register the existence of four bells: the large bell was made by José Antônio in 1763; the second bell was molten by José da Costa Carvalho in 1768; and two other bells were molten in 1773 by Crispim Gonçalves de Oliveira.

On 21st September 1799, the *irmandade* put to the vote and decided for the construction of only one tower and chose the drawing made by João Machado de Sousa according to a receipt of 1801. It seems that the drawing made by Antônio Francisco Lisboa, *O Aleijadinho*, was put aside. In 1810 Miguel Moreira begun to work on the frontispiece; it was finished in 1829 by José Veloso Carmo. Documents of the *irmandade* indicate that the initial drawing of the chapel had two towers, as can be seen on receipts from 1758 to 1783. Three receipts mention services made on the towers of the chapel – one by Mateus Garcia in 1758; another one by Asselmo da Silva Diniz in 1759; and another one in 1782 registers repairs made by Joaquim Roiz Graça on the chapel's towers. The documents indicate the existence of two towers without mentioning any demolition. It is possible that due to the artificial and irregular ground the *irmandade* decided to change the frontispiece and to have only one tower set onto the building.

Starting in 1855, a series of repairs were made on the roof, with the replacement of wooden pieces and the cleaning of the tower and the nave. Four years later there was another repair of the roof and painting of the chancel, the chancel-arch and the side-altars. In the following years the chapel underwent innumerous repairs due to the artificial ground on which it was built. The document sent in 1855 by the *irmandade* to the (then called) President of the Province of Minas Gerais exposes the vulnerability of the terrain. A document of 1862 from the

Secretary of Police of the Province of Minas Gerais reveals another episode of structural works on the chapel's terrain. In 1982 important works of slope stabilization were undertaken on the site of the Chapel of São José.

With a typical conception of the second half of the 18th century, the plan of the Chapel of São José is composed of two storeys. The ground-floor comprises the nave, chancel, presbytery, sacristy, side corridors, and narthex; and the upper-floor has the consistory, tribunes, choir, veranda, and tower. The originality of the building lies on the frontispiece, which is emphasized in the region due to the volume created by de veranda topped by the sole tower. The sides of the veranda are curved and it has masonry balustrade. On the ground floor there are the main door and two false windows. On the upper floor two openings connect the veranda with the choir. The plan of the tower is square with rounded corners. The bell-gables are set high up; on the veranda level there is a large glazed *oeil-de-boeuf*. Documents of the *irmandade* refer to a clock for the tower sent by the Court and offered by the Municipal Council. There are no indications of its installation. A bulbous cupola covers the tower and is sided by four spires. The façade is further back in relation to the tower and it has a framed entablature that differs from the tower entablature. The solution for the closure of the pediment, which is interrupted by the volume of the tower, was given by placing inverted consoles covered by tiles and pyramidal pinnacles on both extremities of the façade.

The nave has four altars; two of them are made in good quality carving and the other two are made in plain wood. The chancel has side tribunes and the high-altar presents excellent quality carving designed by Antônio Francisco Lisboa, *O Aleijadinho*. The altar and retables are good carving works, with columns - straight flutes on the upper part and sinuous flutes on the lower third – on which rest the main entablature and the great external arch; the internal arch, in craving, rests on the entablature, which by its turn rests on pillars created by successive decorated volutes. There are no documents proving the dates of the works of the chancel and the sacristy, which were probably built around 1760. It is also possible that parts of the walls of the old chapel were kept since segments of mud-and-stud walls are found in the chancel.

The atrium underwent changes in the second half of the 20th century, when the floor was raised involving part of the stones of the base of the chapel and the access steps by the frontispiece portal. The cemetery occupies the back and one of the sides of the chapel. It was built in 1832 following a determination of the City Council forbidding the continuation of burials in the interior of the building.

The Church of Santa Efigênia is located on the top of a hill reached by a steep street named Ladeira do Vira-Saia, in the District of Santa Efigênia. It is a beautiful location with an ample view of the town. After reaching the end of the street there are further 42 steps of a wide stone stairway in two flights, closed on its base by iron fence and gate. The Church can be seen from afar, as a small white jewel amongst the Baroque picture of Ouro Preto.

The church was built on the site of a primitive mud-and-stud chapel dedicated to Santa Efigênia and it united the Irmandade do Rosário dos Pretos of the Freguesia de Antonio Dias. The primitive chapel was used by the blacks during a number of years; in 1723 they decided to build the definitive church in masonry and stones from Itacolomi.

The works started in the first quarter of the 18th century. There are records of payments made in 1733 for stone works of the church; between 1743 and 1744 for fences, woods and seats; and for a repair on the towers and works on the roof in 1762, when the works were probably at the end because in this same year the *irmandade* bought the tower clock. In 1777 there was another payment of 400 *oitavas* of gold for stone works. The master of royal works Antônio Francisco Lisboa, *O Aleijadinho*, also did work on the church between 1743-1744, such as adjustments in the chancel and other works on doors, ceilings, fences, seats, and

Figures 6, 7: The Church of Santa Efigênia: in the first half of 20th century (left) and in 2015.Photo by Luiz Fontana IFAC-UFOP archives (left) and photo by Benedito Tadeu de Oliveira.

woods. The church was completely finished in 1785; the date is engraved on the cross above the pediment.

The church lies on a platform and it has an annex; on the left side is the gate of the *irmandade's* cemetery, which was probably built in the 19th century. The frontispiece is divided in three parts, and the central part is projected and framed by quoins with Ionic capitels. The sides of the towers are prismatic with rounded corners, resulting in a curious solution: the convex curved corner is kept on the encounter of the tower with the central part. The large entablature has a beautiful profile; it is curved on the central part, with a trefoil *oeil-de-boeuf* on its concavity. The main portal has a straight lintel crowned by a broken-apex triangular pediment ending on two volutes; it connects with a semicircular arched niche with a carved half-dome resembling a scallop-shell. The niche contains an image of Nossa Senhora do Rosário. The frontispiece is topped by a large pediment, with curves and counter-curves, crowned by a finely stone carved cross. The towers extend above the entablature; both have bell-gables with bells and are crowned by low cupolas with high spires.

In the interior, the choir is above the entrance and it lies on a framed wooden arch; bellow the choir there is a well-finished woodwork windshield. The nave is ample, crowned by a large entablature that is curved above the chancel-arch, which is framed and supported by pilasters with composite capitels. There are four wooden carved altars and retables in the nave, which has a wooden ceiling in an *asa-de-cesto* shape (three-centered ellipse curve). The altars alongside the chancel-arch are richly and lively decorated in an exuberant Baroque-style, with floral motives, consoles, shield-like forms, and two spiral columns supporting the crowning, above which there is a carved border and a crown sided by two angels. The other two altars are each inscribed in an external rectangle with entablature, large border and crown; there are angel figures of different sizes below the entablature; the large main arch surrounded by decoration shelters the niche, which is abundantly decorated with spiral columns and floral motives; these altars belong to a period previous to the two other altars. In the nave the pulpits have wooden carved frames and are made are in carved wood in an urn-shape; they are laid on a sculpted masonry basin. From the chancel there is access to two side corridors that lead to the sacristy. The church contains antique images; some of them represent black saints such as Santa Efigênia and São Benedito, as well as the primitive image of Nossa Senhora do Rosário.

2 DEVELOPMENTS

Figures 8, 9: The Chapel of Bom Jesus das Flores do Taquaral: Restoration works. Museu de Arte Sacra archives, Ouro Preto.

2.1 State of Conservation

The churches of Ouro Preto were all in a bad state of conservation. The different degrees of degradation were due to the following factors: weathering of building materials, lack of preventive maintenance, and incorrect interventions made over the years. The churches maintained their use for religious cults, which means that there was no incompatibility regarding the function of the buildings, so this was not a factor to be held responsible for their degradation. The degrees of degradation varied according to the time elapsed since the latest maintenance or restoration interventions. Another important degradation factor, especially on the wooden and mud-and-stud structures, was the attack of xylophagous insects.

Among the three monuments at issue, the Church of Santa Efigênia was in the worst state of conservation, followed by the Chapel of Bom Jesus das Flores do Taquaral and the Chapel of São José.

The main conservation problems were: precarious state, in some cases with the beginning of the destabilization of wooden structures, especially on the roof; water infiltration and generalized fissures; degradation of architectonic and integrated artistic elements, especially wooden ones; and highly advanced state of degradation of electric and hydro-sanitary installations.The integrated artistic elements such as the retable and the table of the high altar; side retables; chancel-arch; pulpit; nave's baluster; choir's balustrade; windshield; and ceilings of the chancel and the nave, presented the following conservation problems: generalized

Figures 10, 11: The Chapel of São José. Restoration works. Museu de Arte Sacra archives, Ouro Preto.

dirtiness; presence of xylophagous insects; losses and cracks on supports; losses of friezes and carved elements; gaps on the surface of paintings and gilding; painting and gilding with generalized wearing of painting and gilding and on a displacement process; re-paintings and pigmented wax protection coating all over the work, thus jeopardizing its aesthetic characteristics.

The restoration works were constituted of the following stages: thorough architectonic survey; damages mapping; building materials analysis; pictorial and mural prospect; diagnosis of deterioration causes; identification of building systems and of the several transformations undergone by the buildings over the years.

These stages were essential for the development of an intervention methodology and a complete restoration project that had the following main objectives: retrieve the historical and architectonic aspects; retrieve the colors, shapes, volumetric aspects and original inner spatiality of the buildings; modernize installations and infrastructure; preserve the national heritage.

2.2 Interventions

The restoration works at Chapel of Bom Jesus das Flores do Taquaral begun in 2006 and were completed in 2009 having been financed by Banco BNP Paribas. The works at Church of Santa Efigênia begun in 2008 and were carried out in two stages: the first part was financed by Banco Nacional de Desenvolvimento Econômico e Social – BNDES; the second part was financed by the mining company Vale and included the integrated artistic elements, electrical installations, and the external painting; the works were completed in 2011. The restoration works at Chapel of São José started in 2010 and were competed in 2012, also financed by Banco Nacional de Desenvolvimento Econômico e Social – BNDES, besides the World Monument Fund.

Figures 12, 13: The Church of Santa Efigênia. Restoration works. Museu de Arte Sacra archives, Ouro Preto.

The Museu de Arte Sacra do Carmo da Paróquia do Pilar (Carmo Sacred Art Museum of Pilar Parish) administered the three restoration works. The funding received fiscal incentives provided by Lei Rouanet through Programa Nacional de Apoio à Cultura – PRONAC (National Culture Support Programme) of the Ministry of Culture – MinC. The major actions carried out in the three buildings were concentrated on: the repair of the roofs; treatment, reinforcement, and consolidation of the wooden structures; painting according to the original colors; and substitution of hydro-sanitary, electrical, telephony, and atmospheric discharge protection systems installations. Several architectonic elements were retrieved such as entablatures, balconies, stairs, ceilings, floors, wooden frames, masonry floors and segments of mud-and-stud structured walls.

Modern materials were used to substitute all the installations, especially the wet areas with fonts such as nave, chancel and sacristy. In some interventions, due to new necessities or better performance, materials were used that differ from those used in the traditional architecture, such as polyethylene foam aluminum foil sheets. The interventions carried out on the integrated artistic elements were of great relevance and consisted of the following stages: sanitation of ceilings, altars, pulpits, panels and masonry; re-fixation; removal of re-paintings; removal, substitution, complementation and consolidation of supports; treatment against xylophagous insects; leveling; re-integration of gaps; and application of final protection coating. In some cases, original decorative paintings that were covered by layers of paint were revealed. Modern materials were used in these interventions, such as on the protection of painted areas with Paraloid B72 in Xilol at 5% using a brush.

3 CONCLUSIONS

Figures 14, 15, 16, 17, 18, 19: View of the Chapels of Bom Jesus das Flores do Taquaral and São José, the Church of Santa Efigênia; and its surroundings in the first half of 20th century (left) and in 2015. Photo by Luiz Fontana IFAC-UFOP archives, Ouro Preto (left) and photo by Benedito Tadeu de Oliveira.

On the restoration works at the Church of Santa Efigênia, Chapel of São José and Chapel of Bom Jesus das Flores do Taquaral several modern materials, techniques and technologies were used.

Nevertheless, due to the characteristics of these monuments with plenty of decoration; due to the integral legal protection; and also because there were no large gaps within their spaces, no interventions were made with modern architectural elements that could contrast with the old elements.

On the other hand, an important aspect to be discussed that involves modern interventions on a larger scale is the issue of the ambience and the changes on the surroundings of these religious monuments. The projects and intervention works solved the conservation problems of these monuments and followed the modern theory recommendations for the conservation of cultural heritage; but the restoration works did not foresee interventions on their surroundings, such as archaeological excavation projects and landscape treatment. These complementary interventions could re-qualify the sites where these monuments are inserted.

A problem of larger extent is the deterioration of the landscape of Ouro Preto in which the three monuments are inserted. The most deteriorated landscape is in the surrounding of Chapel of Bom Jesus das Flores do Taquaral, followed by the one that surrounds Church of Santa Efigênia, and then the landscape that involves Chapel of São José, where the disorderly urban growth has not been too intense yet.

In Ouro Preto, the cultural landscape to be preserved is the unique ensemble composed of the rich architectural and urban pattern heritage and the entire landscape frame of its surroundings; it has been listed by Instituto do Patrimônio Histórico e Artístico Nacional – IPHAN (National Institute for Artistic and Historical Heritage); and for this reason the entire ensemble has been recognized for its outstanding universal value as a landmark of human creation.

In recent years, the town has been undergoing a process of disorderly urban growth, with the emergence of slums and the occupation of hillsides and geologically unstable areas, green areas, and archaeological sites. This process causes the deterioration not only of the quality of urban life but also of the architectural, urban and landscape ensemble.

With the alterations on the harmonious relationship between nature and architecture – one of its main characteristics – one may consider that the town has been suffering from a systematic and permanent process that combines urban expansion with a practically irreversible loss of character of its cultural and historical landscape. In this sense it can be understood that, with very few exceptions, modern intervention and contemporary architecture in Ouro Preto in general did not provide benefits to the town, due to the loss of character.

The urban landscape requalification of Ouro Preto and the surroundings of these religious monuments is a huge and costly work that involves removals and must be carried out with the use of urban planning tools. But only with such large works it may be possible to grant full architectural visibility to these monuments, as well as providing a significant contribution to the retrieval of cultural, environmental and sentimental values of the town of Ouro Preto.

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STRATEGIES FOR CONTEMPORARY AND CONSERVATIVE INTERVENTIONS IN MONUMENTS CONSTRUCTED IN DIESTIAN FERRUGINOUS SANDSTONE

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Keywords: Traditional and Contemporary Materials, Local Natural Stones, Compatibility and Contrast, Structural and mechanical Behaviour

Abstract.

Introduction:
Ferruginous sandstone is a peculiar type of natural stone which has a ferruginous binder, causing its typical red-brown colour. The most famous Belgian ferruginous sandstone is the Diestian sandstone which was widely used in the 14th-16th century, particularly for the construction of several emblematic Gothic monuments in the region "Hageland". Diestian ferruginous sandstone shows remarkable strengths, such as its heritage value and link with the identity of the local heritage. However, from a building-technical point of view, it has some important weaknesses. It is very susceptible to weathering and there is a lack of qualitative replacement stone. Hence, interventions in monumental constructions built with ferruginous sandstone are a complex issue.

Developments:
To address interventions from a designer's point of view, two approaches were analysed. Firstly, strategies for conservation of monuments, constructed in ferruginous sandstone, are discussed. These include stone repair, grouting and stone replacement. Secondly, case studies with contemporary interventions are presented. In case of 's Hertogenmolens, a watermill in Aarschot (BE), a hotel was added to the historical building, a collapsed façade was replaced by a steel framed wall with Corten steel cladding and a stilling basin was constructed. The second case study concerns the reconstruction of the bell tower of the Saint Willibrordus church in Meldert (Lummen, BE), which collapsed in 2006. In both projects, special effort was taken to relate the contemporary building materials to the historical construction in ferruginous sandstone.

Remarks and Conclusion:
It was concluded that a well-considered combination of conservative and contemporary interventions, with timely attention for structural stability and (public) (re-)use of the building may yield a key to success in dealing with ferruginous sandstone heritage buildings.

1 INTRODUCTION

The paper analyses strategies for interventions in monuments constructed in Diestian ferruginous sandstone. Firstly, criteria and strategies for conservation and repair are analysed. Secondly, two case studies with contemporary interventions are discussed. In both case studies, special effort was taken to relate the contemporary building materials to the historical construction in ferruginous sandstone.

1.1 Diestian ferruginous sandstone

Ferruginous sandstone is a peculiar type of natural stone which has a ferruginous binder, causing its typical red-brown colour. The most famous Belgian ferruginous sandstone is the Diestian sandstone which was widely used in the 14th to 16th century [1]. Most emblematic monuments of the region "Hageland" were constructed in this material, in a local variant of the Gothic style, known as 'Demer Gothic' (Figure 1). The regions where this type of ferruginous sandstone was applied, corresponded largely with the areas of local exploitation. Currently, exploitation sites with good quality stone in adequate quantities are lacking and restorations are often done with debris material from other buildings or with Brusselian ferruginous sandstone, which has a brown-purple colour and is often distinguishable from the red-brown Diestian sandstone. In the late 19th and 20th century, it was even common practice to replace damaged stone material with infill brickwork.

In historical monuments, Diestian ferruginous sandstone masonry walls are mostly composed as three-leaf masonry, a common masonry construction typology also encountered for brick masonry or other types of historical natural stone masonry (Figure 2). The outer layers are composed of regular sandstone blocks, while the inner core consists of irregular sandstone chunks and lime mortar. The stability of the wall is assured by the confining effect of the stiffer outer layers.

1.2 Material characteristics and pathology

In general, Diestian ferruginous sandstone has rather poor mechanical characteristics: it has a low overall compressive strength and there is a relatively large scatter on these strength values within one building block as well as in comparison between different stones (Figure 3). Additionally, the sandstone easily absorbs water, which reduces the strength and stiffness even further [2].

Figure 1: Saint Sulpitius church (in Diest, Belgium), an emblematic example of "Demer" Gothic style, constructed in Diestian ferruginous sandstone

Figure 2: Section of a wall constructed in three-leaf masonry with regular outer masonry and core infill in ferruginous sandstone

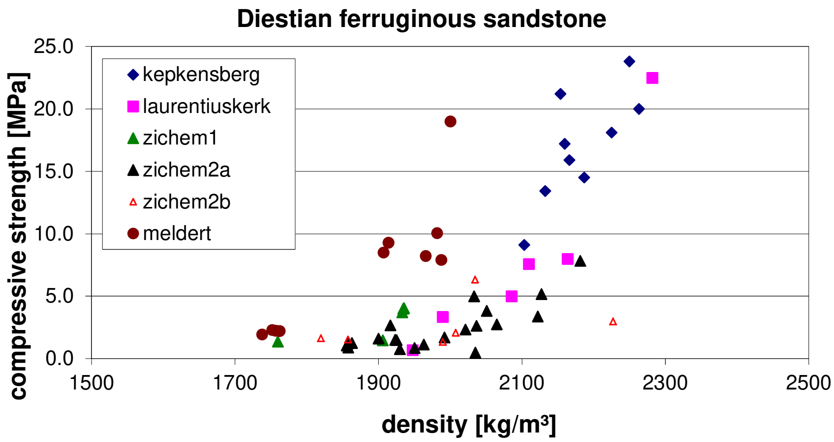

Figure 3: Uniaxial compressive strength versus density of Diestian ferruginous sandstone, experimentally tested on core samples from three different monuments and one quarry site

Therefore, the outer surface of Diestian ferruginous sandstone is vulnerable to weathering in the long term. Crusts are formed due to migration of minerals, caused by water infiltration. After removal of the crust, a softer material layer is suddenly exposed to weathering influences. General weathering phenomena, which can be found in softer and porous stones, such as spalling due to freeze-thaw cycles and erosion by water and wind, are also present.

Besides the weathering of the exposed surface material, a second major issue is the low compressive strength of the masonry and the large scatter of these strength values. This makes the material vulnerable to creep effects and mechanical deterioration. Especially in taller structures, such as church towers and medieval city towers, the stress level at the base of the construction is high compared with the strength of the masonry [3].

A specific issue, which can be categorised as biological deterioration, is the presence of bees which make their nest in the soft sandstone, decreasing the strength and coherence of the stone with a network of holes. However, this phenomenon generally does not lead to large-scale structural problems.

2 STRATEGIES FOR CONSERVATION

2.1 Criteria

When dealing with monuments, constructed in a local natural stone which is prone to weathering and has relatively low strength properties, a variety of criteria is to be taken into account in the assessment of intervention approaches. On one hand, restoration interventions such as stone replacement and the application of repair mortars are to be durable, compatible and esthetically acceptable, on the other hand, the overall structural integrity of the monument is to be investigated and assessed.

To illustrate the difference between an esthetical and structural intervention, and to stress the importance of both, following remark found in the transcript of K. Bos (1989) concerning the restoration of the Saint Willibrordus church in Meldert, is cited:

“In more severe cases of surface erosion it may be necessary to chop off an outer layer of 2 to 3 cm all around the building. This system was used during the restoration works of the Saint Willibrordus church in Meldert. The results are very good…” [1].

The tower of the Saint Willibrordus church however collapsed on July 6th 2006. It has to be remarked that this collapse, which was due to long-term accumulation of creep damage, was triggered by a combination of effects: the relatively low strength of Diestian ferruginous sandstone combined with the lack of internal cohesion within the three-leaf masonry and the increase of stresses at the base of the tower during the widening of the tower entrance. During this latter intervention, carried out in the 1970-ties, the outer sandstone layers were not fully replaced, leaving some of the core masonry only covered by a layer of plaster [4].

In the next section, several restoration approaches are discussed. There is not always a complete distinction between esthetical and structural interventions, however, most interventions tend more towards either a decrease or prevention of surface weathering on one hand or strengthening solutions for structural integrity on the other hand.

All interventions within historical monuments have to be judged within the framework of international charters and guidelines. The ICOMOS Charter on “Principles for the analysis, conservation and structural restoration of architectural heritage [5], indicates that interventions should be <u>reversible</u> when possible (principle 3.9), <u>compatible</u> and without future undesirable side-effect (principle 3.10), <u>recognizable</u> and documented (principle 3.12) and executed in a <u>controlled</u> manner (principle 3.19).

2.2 Options for restoration and retrofitting

With regard to severe surface degradation treatment, a division can be made between techniques which can be applied without removing the building blocks, and interventions which require (temporarily) removal of stones from their position. Examples of the former are:

- <u>Stone consolidants</u>: For Diestian ferruginous sandstone, consolidants such as ethyl-silicate have most effect on good quality stones and are only effective for a restricted depth [6]. They could be a solution for protection against weathering influences, but not for stones which are already severely damaged.
- <u>Repair mortars</u>: In the development of repair mortars for ferruginous sandstone, encountered difficulties are: obtaining a correct color with long-term stability, and the compatibility with the old material concerning strength and stiffness, but also regarding moisture transport. Repair mortars often have restricted durability as the added material is easily loosened from the original stone due to temperature and moisture cycles.
- <u>Plaster and lime wash</u>: Some monuments constructed with ferruginous sandstone still show traces of older layers of plaster which were applied to protect the sandstone from weathering influences. This protective layer would also have had a positive influence on the structural behavior of the masonry, as it prevented moisture ingress and deterioration of the mortar and sandstone itself. The (re-) application of such white plastering layers would completely alter the current appearance of monuments, constructed in dark-brown Diestian ferruginous sandstone.
- <u>Rectification</u> of stones: The weathered outer surface can be smoothened by rectifying the wall as a whole or stone by stone. The former technique reduces the outer layer of the masonry by several centimeters, which might degrade the structural integrity of the masonry.

Techniques which require the temporarily removal or replacement of stones:

- <u>Replacement stone</u>: The damaged Diestian sandstone blocks are often replaced by Brusselian sandstone, which is a comparable material with better durability (more cohesive) and quality, but which has a different brown-purple color. This option is a rather expensive solution as the availability of Brusselian sandstone is also limited. Unlike

Diestian sandstone, the Brusselian sandstone does not contain glauconite. Brusselian ferruginous sandstone is coarser-grained and has a more homogeneous grain size distribution and a much faster capillary absorption.

A negligent use of above mentioned techniques can lead to structural integrity problems. Therefore, a structural assessment is required in case of large-scale stone replacement or when signs of structural damage, such as larger, vertical cracking, are present. Options for increase of load-bearing capacity and/or internal cohesion of the three-leaf masonry are:

- Grout injection: This is a general solution to increase the masonry's strength and coherence. Main issues are the compatibility between the grout and the original material and the fact that a lot of water is injected in the masonry, which has a temporary negative effect on the masonry's stability. If no precautions are taken during the injection and hardening period, this can cause instabilities and (local) collapse.
- General strengthening options for masonry can be applied, such as steel anchorages and confinement of columns. These interventions are not specific for ferruginous sandstone.

2.3 Restoration example

To illustrate the application of these techniques, the restoration of the Maagden tower ("Maagdentoren", Zichem, Belgium) is discussed. The Maagden tower, a free standing tower probably constructed in the 14th century as part of a defense infrastructure [7], partly collapsed in 2006 due to increasing lack of inner cohesion of the masonry and long-term damage accumulation under the tower's self-weight. The tower is constructed in Diestian ferruginous sandstone in a typical three-leaf masonry layout and the surface of the remaining sandstone masonry is heavily deteriorated by weathering and stone bees (Figure 4). Immediately after partial collapse, the remaining part of the tower was secured with circular tie rods at different heights and the top was covered with a temporary plastic roof to prevent further deterioration of the masonry by water infiltration.

Currently, a two-phased restoration process is ongoing. The first phase includes a grout injection of the three-leaf masonry, stabilization of the incomplete vault, fixation of the remaining paintings on the vault, and renewal of the collapsed part by means of masonry in hand-moulded, red clay bricks and an interior staircase. The second, currently ongoing, phase concerns the restoration of the outer surface of the ferruginous sandstone masonry.

The concept of the restoration is such that the monument will be kept as a "ruin" and used as a watch tower. Therefore, it was opted to keep as much of the original Diestian ferruginous sandstone as possible while reducing stagnation zones for rain water to prevent frost damage. Since stone consolidants were judged to be inefficient during preliminary studies and large-scale use of Brusselian ferruginous sandstone was to be avoided due to a difference in color, a patchwork of solutions will be combined: severely deteriorated stones are replaced by new ferruginous sandstone, large gaps are filled in with clay brickwork (similar to older repairs), specific stones are slightly rectified and local, smaller gaps are filled with repair mortar [8]. This restoration is to be concluded by mid-2015, after which the combined solutions and their durability can be assessed.

Figure 4: Heavily deteriorated ferruginous sandstone surface of the Maagden tower (Zichem, Belgium)

2.4 Research priorities

A local expert group has been set up to address the current shortage of replacement stone for urgent restoration projects and provide a scientific base for the understanding and management of the issues concerning Diestian ferruginous sandstone. In addition, meetings are held with contractors, architects, distributors and producers of stone treatment products and local symposia are organized to disseminate information and increase awareness for this precious local natural stone. Within the expert group meetings, following research priorities have been defined:

A. Applied research to obtain the much required material for restoration projects:
- Application of other stone types as replacement stone. Compatibility is required, not only in terms of color, patina and weathering, but also in terms of mechanical behavior and pore structure (water transport). Examples are Brusselian ferruginous sandstone, English ferruginous sandstone (compatibility still to be investigated);
- Further exploration of possible sites which could serve as small-scale, local quarries for Diestian ferruginous sandstone;
- Production of artificial ferruginous sandstone, using crushed ferruginous sandstone as one of the major components.

B. Fundamental research to enhance the understanding of the durability of Diestian ferruginous sandstone and the effect of the different weathering processes:
- Investigation of the driving processes behind the crust formation;
- Composition of the clay fraction and its influence on the mechanical behavior;
- Moisture-induced effects, such as partial (saturation), pore liquid transport and freeze-thaw cycling on the sandstone's mechanical behavior and durability;
- Relation between techniques applied on site and in laboratory environment to determine the quality and consolidation degree of the stones.

3 CONTEMPORARY INTERVENTIONS: CASE STUDIES

3.1 Case study 1: 's Hertogenmolens (Aarschot, Belgium)

The construction of the current buildings of the watermill started in the early 16th century with a mill on each bank of the river Demer and a central lock. The central building was erected by the end of the 16th century. The substructure of the buildings was constructed in masonry with a striking layered pattern of white natural stone and brown Diestian ferruginous sandstone. The upper structure consisted of red clay-brick masonry. Additional buildings were added during construction phases in the 18th and 19th century. After its last use in the 1960 for crushing of glass, the mill and buildings rapidly degraded. After a fire in 1970, the northern side wing was demolished. In 1986, the year in which the watermill and its buildings were protected as monument, the façade of the southern side wing collapsed due to severe structural instability. Figure 5 shows the situation at the start of the renovation, with the collapsed façade closed up with temporary panelling.

At the start of the renovation, serious material degradation had occurred and severe structural problems were present. Differential settlements of the foundations had caused large cracks and instabilities in the masonry. Water flux had washed away the soil surrounding the wooden pile foundations which had left the foundations exposed. Therefore, structural interventions were to be carried out before restoration of the existing buildings and addition of new parts. The foundations were strengthened with micro-piles, a retaining wall and new concrete floor slabs above the wooden pile foundation. Three stilling basins were created to reduce the water flux in a controlled manner. The cohesion of the masonry was improved by short anchors for the stitching of cracks and larger anchors to connect the eastern and western façades. The original wooden floor beams were kept as much as possible and if needed, deflections were reduced by means of externally bonded wooden beams or steel plates [9].

In terms of architectural renewal, two major interventions were taken which both refer to the importance of Diestian ferruginous sandstone for the identity of the region's monuments. Firstly, the collapsed wall was replaced by a new wall covered with Corten steel cladding. Secondly, a new hotel building was added on the northern side, constructed in concrete which is colored by the addition of iron oxide. All three materials, the original Diestian ferruginous sandstone, the Corten steel and the colored concrete will age differently and show their typical patina and degradation processes. Hopefully, they will do so with respect for each other and the history of the site and its buildings.

Figure 5: 's Hertogenmolens (Aarschot, Belgium), situation at the start of renovation works

Figure 6: ‘s Hertogenmolens (Aarschot, Belgium), situation after renovation

Figure 6 shows the situation after the renovation in 2010. The design followed an instinctive restoration and renovation approach, with attention for structural integrity and adapted reuse of the buildings. The renovation design by noAarchitecten has received the European Union Prize for Cultural Heritage / Europa Nostra award in 2011 in the category “conservation”.

3.2 Case study 2: Saint Willibrordus church (Meldert, Lummen, Belgium)

The Saint Willibrordus church in Meldert (Lummen), in Belgium, has known many alterations and additions during its construction history. The oldest evidence of the origins of its construction are the foundations of a single-nave Roman church. The foundations, the medieval bell tower and the base of the nave, choir and aisles are constructed in ferruginous sandstone, while later additions are made in clay brick masonry (Figure 7). The barrel vault in the nave and rib vaults in the aisles are constructed in plastered wood. Changes to the church layout have been carried out in the 17th -18th (nave, aisles, transept and choir), 19th (aisles, transept and addition of chapels on either side of the tower) and 20th century (thorough restoration in the 1970s after listing of the monument).

The latest alteration took place in the 21st century with the collapse of the medieval bell tower and part of the nave and aisles in 2006 and addition of a new bell tower in 2013. After investigation of the foundations and crack pattern, the large cracks and subsequent collapse of the tower have been attributed to instability of the masonry, which was caused by long-term deformations, loss of inner cohesion and creep effects as explained in Section 2.1 [10].

There were three options for the restoration concept for the collapsed tower: reconstruction, replacement by a new tower or omission. The search for the causes of the collapse learned that the ferruginous sandstone of the tower masonry was heavily eroded and could not be reused, disabling the possibility for reconstruction of the historical tower. Therefore, the only remaining options were a new tower or omission of a church tower. Many elements play a role in this decision. An important element is the societal function of the tower. The church and especially the tower have been a landmark of the community for centuries. Loss of such landmark might have an important effect on the village community. But the church tower also plays an important role in the force distribution in a church building: it ensures the vertical flow of self-weight and counteracts the horizontal components of forces generated by the arches and vaults of the nave, and the tower and western façade also have to resist the wind forces [4].

Figure 7: Saint Willibrordus church (Meldert, Lummen, Belgium), situation before collapse of the tower

Figure 8: Saint Willibrordus church (Meldert, Lummen, Belgium), situation after reconstruction of the tower

Figure 8: Saint Willibrordus church (Meldert, Lummen, Belgium), structural detail

Figure 9: Saint Willibrordus church, visualization of omitted side chapels with debris material

These elements were taken into account within the design of the new church tower, which consisted of a concrete basement at foundation level and a lightweight steel substructure. The steel structure was anchored to the basement and finished with Corten steel cladding. While the historical west façade and tower obtained their strength from their enormous self-weight, the strength and stiffness of the new, lightweight structure is assured by its layout, its volume and the mechanical anchorage to the foundations. A metal arch structure was introduced to replace the missing part of the nave wall, and thus to assure the connection between the nave wall and the tower to withstand the horizontal forces coming from the masonry arches (see Figure 8).

The side chapels on either side of the tower were not replaced but visualised with framed boxes, filled with remains from the collapsed tower (see Figure 9). The ferruginous sandstone filling does not refer to the masonry of the omitted chapels, which were completely built with clay-brickwork. It refers to the importance of the Diestian ferruginous sandstone and the historical tradition of its quarries for the region. The Corten steel cladding of the tower will form a stable rust patina and again was applied to refer to the original rust-brown colour of the historical, ferruginous sandstone tower [11].

4 CONCLUSIONS

- Any intervention in historical monuments should be considered from the viewpoint of international restoration criteria and from the viewpoint of the local history and community to effectively protect its heritage values.
- In addition, any structural intervention requires a thorough structural analysis to ascertain the building's long-term structural stability and integrity.
- An urgent focus on a number of research priorities is required to develop adequate strategies for near-future, sustainable interventions in the numerous heavily deteriorated monuments constructed in Diestian ferruginous sandstone.
- A well-considered combination of conservative and contemporary interventions, with timely attention for structural stability and (public) (re-)use of the building may yield a key to success in approaching ferruginous sandstone heritage buildings.

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SYNTHETIC OF ARCHITECTURAL DETAILS USING 3D MODELLING AND 3D PRINTING

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Keywords: Built Heritage, Ornaments, Details, 3D Printing, Replica

Abstract.

Introduction:
The architectural heritage is the background of our urban life; it preserves and enhances our identity.
The bulk of our heritage consists of average historic buildings still in use, exposed to decay and restructuring. Such buildings exhibit beautifully crafted decorations and details which are likely to disappear in time. The loss is due the lack of maintenance and the downfall of handicraft. For these reasons we have experimented with a new methodology which can generate accurate replicas of the damaged and missing details within heritage buildings. Replication has always created argumentation..

Developments:
The entire process is based on the 3D modeling of the existing elements, followed by virtual manipulation, resulting in the 3D printing of an accurate replica. There are three main steps to the process. The first step is the collection of data about the studied object by using either laser scanning or digital photogrammetry, the second one being more cost effective. Data processing is the second step, along with the generation of a 3D model. Successive modeling is required in preparation of the 3D printing. The third step is the printing itself. We tried to reproduce a polychrome ceramic ornament from the Great Synagogue of Timisoara (1865). In order to produce a convincing replica, several printing technologies and materials were used starting with FDM-PLA (filament) to the more advanced SLS (stereolithography) using polyamide 12, to the advanced Pro Jet (powder, infitrate and CMYK binders) and PolyJet (photopolymers). Pro Jet produced the best results reproducing color and texture.

Remarks and Conclusion:
Although the request of material authenticity is not respected, the use of modern imaging and replication technologies has already produced impressive results in restoration. We restore with a purpose and our purposes are open to debate.

1 INTRODUCTION

Built heritage is a substantial component of our "Cultural heritage", an expression of the ways of living developed and passed from generation to generation by a community, an expression of its shared valued and beliefs.

The built heritage is a component of our Tangible Heritage (Icomos 2002); cityscapes and heritage buildings make cities unique and able to preserve and enhance our shared identities.

Our own city, Timisoara, the westernmost city of Romania, is a living proof of the important role the fabric of heritage buildings and public spaces play in our daily life.

Timisoara is a city almost 750 years old, but very few material remnants from this distant past were preserved.

It was an angevine outpost in medieval Hungary, the capital of a vast region called Banat, a Turkish city (between 1541-1716), the main city of a habsburgic province and after 1918 a Romanian city.

Its present shape was forged continuously between mid XVIIIth and early XXth century, the decisive pre-modern era of Central Europe – Mitteleuropa. [1]

It was only recently that a complex urban renewal project allowed for the archeological uncovering of a more distant past.

Figure 1: Timisoara map (1893)

The city has an inner core, The Citadel, where the main institutional buildings were disposed along a perfect octagonal grid enclosed inside a formidable Vauban fortress; around the nucleus were several satellite towns, each displaying an unique character. When the fortress was leveled, in the late XIXth century, the satellites and the core were reunited into an urban continuum imagined by the famous architect and urbanist Ludwig von Ybl in 1899. [2]. (figure 1)

Figure 2: Timisoara historic buildings and Unirii Square

It is the consistent fabric of this urban tissue connecting the historic nuclei that gives Timisoara its unique identity; thousands beautiful houses (figure 2) displaying magnificent constructive and architectural details and beautifully crafted ornamental patterns [3].

Beside a few dozens of high-rank monumental heritage buildings, the bulk of our urban heritage consists of this average historic buildings still in use today, still an essential part of our day to day “ambiente”.

The same condition is to be found in most central European cities and in western European cities as well.

Figure 3: Historic building in the Citadel, before and after restoration

These buildings (figure 3) are exposed to the effect of pollution, weathering, changes in use and even unfortunate tentatives of remodeling and restructuring. Labeled “minor architecture” in contrast to major monuments, such buildings are supposed to benefit from “reduced” or “simplified” recovery proceeding, as background for “important” heritage structures.

Figure 4: Damaged ornaments in a historic building

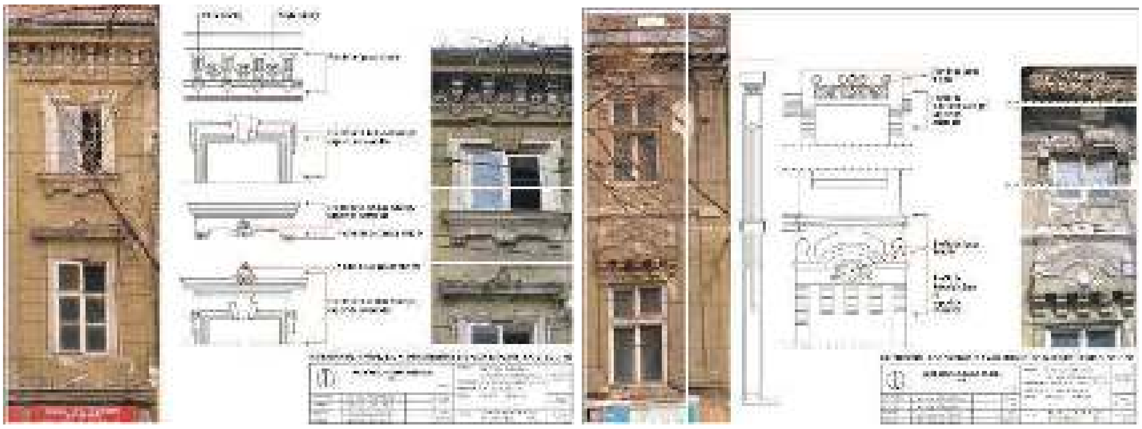

Figure 5: Assessment of an historic facade

When it takes place, each intervention impoverishes and mutilates the ornamental wealth of these buildings, affecting the special qualities of the urban space.

In my personal practice, over several decades, I have always respected the position of P. Philippot, who sustained that it is an ethical and cultural must to carefully preserve the image of the premodern city from late XIXth and early XXth century, without favoring supposedly more “important” periods [4] without favoring supposedly more important periods.

There are several causes for the accelerated decline of these unique buildings (figure 4,5): first – the decline in both public and private funding for the maintenance and restoration, correlated with the sheer number of such buildings. The traditional assessment proceedings – restoration survey, materials assessment are time consuming and expensive and so are the costs of intervention.

Figure 6: Timisoara building restoration and consolidation (2004)

In the field of structural consolidation new technologies are accepted (Figure 6)– carbon fiber, steel – in surface restoration there is a general consensus about preserving the time honored traditional crafts which brings us to the second cause of decline – the dramatic downfall of handicraft which causes poor results in work quality and loss of precious details.

Generally, “minor” architecture in Mitteleuropa displays brick structures, wooden floors and attics, plaster finishing and plaster, ceramic, metal and wood ornaments. The materials are of average quality but the craftsmanship is exquisite.

In the last twenty years in our country craft techniques were replaced by of-the-shelf industrial technologies, art and craft schools were closed and the time-honored apprenticeship system almost disappeared. The very few available artisans have become cultural heroes, but cannot respond to the huge demand. The process started even earlier in most western countries.

Figure 7: Verona, Castelvecchio intervention by Carlo Scarpa

Figure 8: Stairway detail Musée Maillol Paris

The temptation to use modern materials and techniques in the restoration field has generated the prevalent aesthetics of “contrast”, a vulgarization of the remarkable Castelvecchio (Verona) intervention of Carlo Scarpa (figure 7) some fifty years ago. [5]

Instead of this approach we propose a methodology which can generate accurately reproduced elements that can replace damaged or missing details and ornaments within heritage buildings, by using high tech imaging and 3D printing techniques.

This approach will obviously trigger a theoretical debate about *authenticity, patina, replica, simulacrum* etc.

The exact replication of the Lascaux site and artifacts (1984) attracted Jean Baudrillard’s comment that both the original and the replica undergone a loss of meaning – becoming “both artificial” sophisticated and expressive. [6]

The instalation of a high tech replica of the famous Marcus Aurelius equestrian statue in Campidoglio and the “museification” of the original inside a pavilion designed by Calro Aymonino (figure 9) produced a heated debate between W.Veltroni the contemporary minister of culture – praising the protection of the original and the former director of the Central Institute of Restoration – which considered the action as “ an attack on decency, good taste and culture.”[7]

Figure 9: Marcus Aurelius equestrian statue in Rome: original and replica

It is a never ending story so let's proceed with the experimentation.

2 DEVELOPMENTS

The process is based on data collecting, the 3D modeling of the existing elements, allowing for further virtual manipulation and resulting in the accurate 3D printing of a replica of the chosen elements.

The printed elements installation on the site is becoming easier, less-specialized and, evidently cost-efficient.

Figure 10: The Great Synagogue from the Citadel of Timisoara

In order to test the proceedings we have chosen the "Great Synagogue" from the Citadel of Timisoara, (figure 10) inaugurated in 1865 by the emperor Franz Joseph I. This centrally shaped and domed brick building is enveloped in an "moorish-andalusian" decorated façade and stands out for both civic dignity of the newly emancipated Jewish community and its desire to integrate in the modern society.

Figure 11: Ornament ceramic tiles, the Great Synagogue from the Citadel of Timisoara

Our choice was an ornamental ceramic tile from the main façade, measuring 23.3 x 23.3 x 3.5 cm. (figure 11)

There are three steps in the process of producing an accurate replica

- **The first step** is the collection of data about the studied object by laser scanning or digital photogrammetry.

Figure 12: Data colection

Our first choice was digital photogrammetry because it can be done with commercial available cameras and it is more cost effective than high performance laser scanning.

Through photogrammetric procedure (figure 12), successive overlapping photos of the object are taken (75% - 80% overlap)

Accurate scaling is obtained by using reference markers. In connection with the photogrammetric data collection, one of our collaborators, mr. Lucian Vuicin (from Helicam S.A. high-tech imaging firm) imagined a Linear Motion Central System for Digital Photogrammetric Survey; the system is comprised of three elements:

- An ultra-light modular tress structure constructed from carbon fiber and assembled via special aluminum connection
- A motorized four axis camera mount made of carbon fiber
- A programmable electronic controller

Although it was not available during our data collection, it could seriously improve the speed and accuracy of the photogrammetric process, especially for archeological and architectural applications.

We also tested a consumer 3D scanner and a semi-pro "point and shoot" 3D scanner, but finally we processed the photogrammetric data collection.

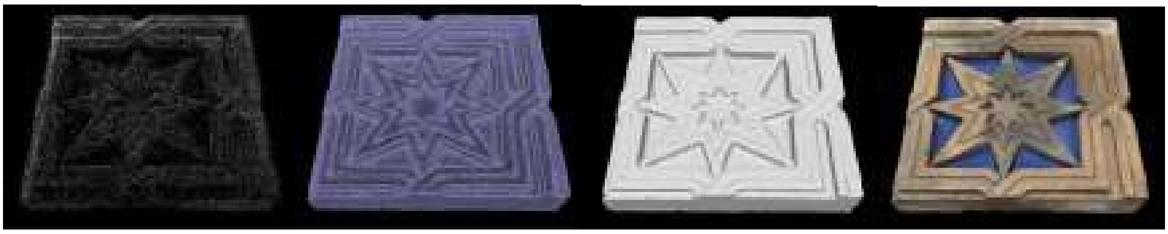

Figure 13: Data processing: element cloud point, wireframe, solid, solid textured

- **<u>The second step</u>** was data processing (figure 13) using available software as "BDModeller" or "Photoscaner". The steps were: element point cloud, element wireframe, element solid and finally the element solid textured.

- **<u>The third step</u>** was the 3D printing itself. This step was preceded by an assessment of the available 3D technologies, materials and finishes

After exploring both the consecrated and the newer, innovative technologies, we have chosen the following printing technologies and materials: <u>FDM-PLA</u> (Fused Deposition Modeling – Polyactide Resin – filament) <u>SLS</u> – `Polylaurinlactctam (Laser Sintering or Sterolithography – polyamide 12, nylon 12), <u>ProJet</u> – powder infiltrant & CMYK binders, <u>PolyJet – Photo Polymers</u> (Polymerised Vero White Plus) and the <u>mcor</u> (A4 standard office paper).

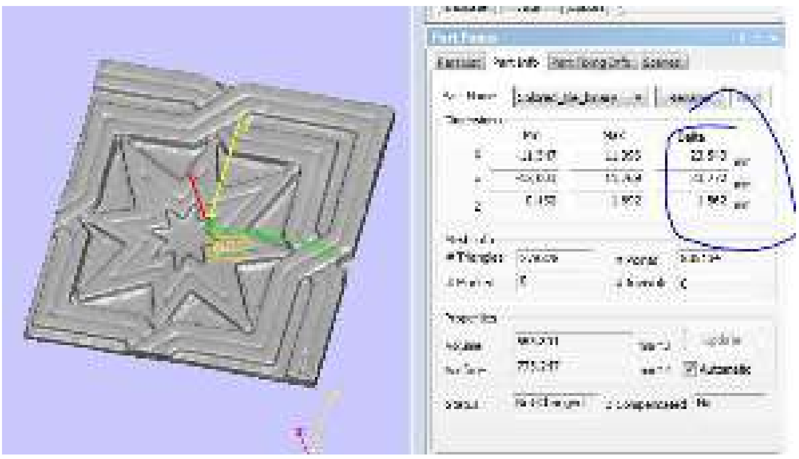

Figure 14: 3D model validation

Before the 3D printing, a 3D model validation process is necessary (figure 14). The process has six steps:

1. **Size check** – the physical boundaries of the 3d print machine wall thickness
2. **File format check**
3. **Is the file in the standard (STL, PLY, OBJ) format?**
4. **Polygon count check**
5. **Normals check**. Face normals define the “inside” and “outside” of the model
6. **Manifoldness check**. Due to the nature of the 3D printing process, all models need to be closed, manifolded objects. Manifold means that each edge in the model is shared by exactly two faces- not more and not less. Manifolds objects are always closed.

The analysis of our five print technologies produced the following results:

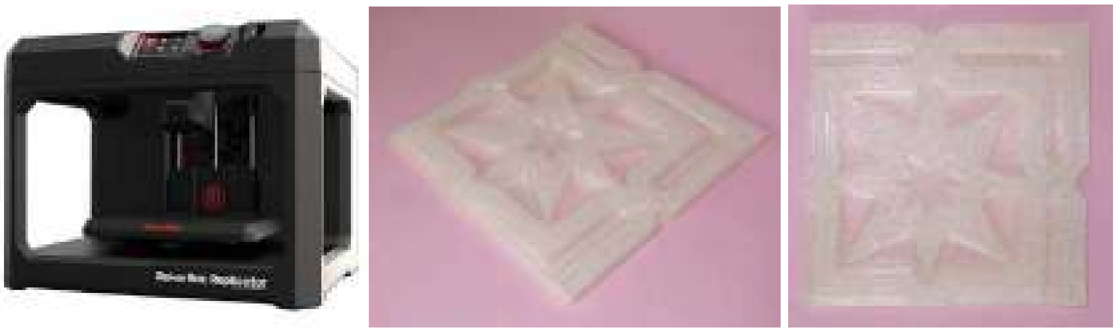

Figure 15: FDM-PLA printing machine and result

1. The FDM-PLA (figure 15) produced a cheap (6-8 €) monochrome (white) textured copy of unconvincing quality

Figure 16: SLS printing machine and result

2. The SLS – Polylaurimlactam (polyamide 12), Nylon 12, (figure 16) produced a rather expensive (64.53 €) monochrome (white) geometrically accurate replica – we gave up the next step: the manual coloring of the tile (254€)

Figure 17: Pro-Jet printing machine and result

Figure 18: Real model

3. The Pro-Jet – powder infiltrate & CMYK binders (figure 17)technology produced an impressive replica in terms of geometry, texture and perfect reproduction of colours. The price for a tile was rather important: 210.75€ but the potential cost reduction in case of extended use is considerable.

4. The PolyJet - (Polymerised Vero White Plus) technology was apparently a winner both in terms of cost (€122.50) and quality. In fact the color programme failed to perform.

5. The mcor - A4 standard paper + colored inkjet cartridges, a new and revolutionary 3D printing technique could not be tested because of a communication breakdown with the mcor partner.

The experience was enlightening: this is a field in full development, new technologies appear periodically and the potential is huge.

Even the trivial FDM-PLA can be used with success if covered by paint or plaster. The more evolved SLS (Laser Sintering) and the sophisticated ProJet are able to produce high quality replicas. The high cost of the experimental testing could drop quickly in case of extended use.

3 CONCLUSIONS

- The rapid development of technology is fundamentally challenging our approach to the built heritage. A large array of miniaturized sensors (laser, photo, UV, X-ray, spectrograph) are available as well as new technical means of exploration (drones, satellites).

We are able now to explore and model our built environment with great accuracy and we can store these models (including the kind of precise 3D solid model we have used) in virtual archives.

The 2D and especially the 3D printers are allowing us to produce amazing copies and / or replicas of the most complex artifacts.

- In 2006, the “Fondazione Cini” reached on an agreement with Louvre museum and granted “Factum Arte” the permission to produce a full scale high-tech replica of the Veronese's painting "Les Noces de Cana" destined to the Cenaclo Palladiano in the Convent “San Giorgio Maggiore” in Venice. (figure 19)

Figure 19: Cenaclo Palladiano in the Convent "San Giorgio Maggiore", Venice

The working methodology was similar to ours: A photo scanner using large CCD sensors scanned the painting mounted on a precision telescopic mast. The data was pre-assembled using Photoshop scripting and colors adjusted using high quality photographs.

The printing was done using a purpose built flatbed printer on gesso coated canvas. The result was placed in the Cenaclo in order to reproduce the original outlook of the space. It was generally considered a huge success. [8]

• This approach brings us to the controversial problem of authenticity in restoration.

After all as Cesare Brandi warned some time ago that restoration is essentially a product of its own time asnd space and it's an act of critical interpretation. [9]

Managing weathering and damage, completing for the losses are central to our care for the built heritage.

We have always a purpose when we restaurate and that purpose is evolving continuously and is always open to debate.

We are acting in our own time, influenced by our realities, technologies, values and perceptions.

• P. Philippot indicated that: "authentic relationship with the past must not only recognize the unbridgeable gap that has formed , after historicism, between us and the past; it must also integrate this distance into the actualization of the work produced by the intervention". (10)

Some problems as the patina are to be considered as Brandi itself remarked: on a case by case scenario. (11)

Francoise Choay was expressing her hope that architecture has an important memorial role to play despite the loss of our " competence d'edifier" (12), namely our capacity to build and transfer meaning in the traditional way.

• I am still optimist - after all we want to preserve what is our " ambiente" using with insight the means provided by our evolving technology.

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ANALYTICAL MODEL OF *FRM* (FIBER REINFORCED MORTAR) MASONRY PANELS: ANN APPROACH

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Keywords: Shear, Strengthening, FRM, Masonry

Abstract.

Introduction:
The current pursuit aims to provide an innovative analytical model for the prediction of in plane shear strength of masonry panels retrofitted with fiber reinforced mortar (FRM) composites. The use of fiber grids and inorganic matrix (cement, lime, recycled materials, etc.) is becoming popular for retrofitting the masonry walls. The strengthening technique, considered in this study, consists of the application of an inorganic mortar reinforced with fibres mesh on both faces of the masonry wall and anchored in some cases to the masonry surface by means of suitable connection devices.

Developments:
In this scenario, Artificial Neural Network (ANN) based analytical techniques find application. An ANN procedure is presented in the paper, showing how well it finds application in the civil engineer field. The aim of the paper is to present a new analytical model for the shear strength prediction of FRM strengthened masonry. An approach in between a full theoretical method (which can maybe provide the best model, but considering complicate mathematical forms, making it difficult to use) and a large scale test and parameter calibration (which required large set campaign in order to consider all parameters involved in the phenomena, which is not sustainable from the economical point of view) is illustrated.

Remarks and Conclusion:
Depending on the choice of the matrix used, the FRM are successfully adopted also for historic masonry structures strengthening. The lime mortar is commonly embraced in order to preserve chemical, thermal and mechanical compatibility with the substrate. With a relatively small input database of laboratory test, ANN is able to provide a theoretical solution to the problem with acceptable accuracy and precision. It will be shown how to easily predict the shear failure of masonry walls strengthened on both sides with innovative FRM systems under in plane shear loads.

1 INTRODUCTION

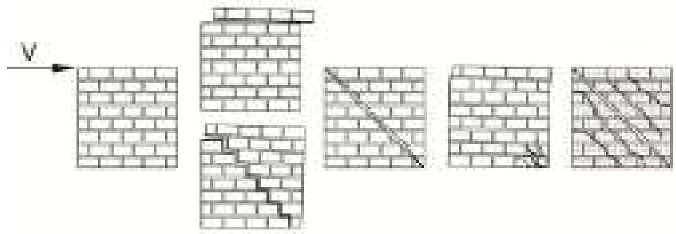
The analysis of masonry panels retrofitted with Fiber Reinforced Mortar (FRM) has been the subject of recent scientific studies. In order to consolidate or strength a masonry wall subjected to horizontal in-plane force, like dynamic action (earthquake, wind, etc.) besides to gravitational loads, is very important to reach an acceptable security level. The weakness of the masonry mechanical characteristics, such as the shear strength, is well known and it is often cause of the collapse or serious damage in historical buildings, for example during seismic events. Various techniques are currently used for the reinforcement of masonry construction like:

- Impregnation with organic consolidating;
- Injection;
- Stitching by steel reinforcement;
- Reinforced plaster;
- Application of FRP (Fiber Reinforced Polymer).

The FRM is a kind of reinforced plaster with the coupling of a network fiber of high performance and a stabilized inorganic matrix used as adhesive, which replaces the epoxy resins of FRP traditional systems. This technique consists of applying a layer of mortar (cement or lime mix to fine particle size), with a minimum thickness of 4 – 5 cm, reinforced with welded mesh, if possible on both faces of the wall to be consolidated. The choice of the material of the matrix depends on the type of structure to be reinforced; cement mortar is commonly used for concrete buildings while lime mortar is preferable for historical masonry heritage. The contact between similar materials guarantees the best chemical, thermal and mechanical compatibility. The disadvantages consist in an increasing of the thickness of the wall, even if only slightly; in addition the technique is not applicable if the view of the rustic wall should be preserved. The reinforcing procedure can be briefly summarized as follows: the existing plaster must be firstly removed, thus specific holes are drilled, in which the connecting brackets will be passed through; after having placed the welded mesh, the wall is wetted and a mortar layer is finally applied. The result is the realization of two small reinforced concrete walls interconnected in the transversal way (metallic or non metallic connectors).

1.1 In-plane shear response of masonry

A shear wall's in plane capacity derives from the geometrical and mechanical properties of the wall, such as compressive and tensile strength, bond strength at the interface bricks-mortar. The main in-plane failure mechanisms of masonry panel subjected to shear actions are summarized in Figure1.



(a) (b) (c) (d) (e)

Figure 1: Masonry shear failure modes: (a) Safe masonry subjected to in plane horizontal force; (b) sliding; (c) diagonal crack; (d) toe crush; (e) diagonal cracks in grid-reinforced masonry

A horizontal force V is supposed to act on the longitudinal mid-plane of the masonry wall (Figure 1 (a)). *Sliding* is a typical failure mode in case of low vertical loads and/or low friction between bricks and mortar joints. The cracks are therefore formed in the bed joints followed by sliding on the upper part of the wall. These cracks may follow the horizontal or the stair-stepped direction passing the vertical and horizontal joints, depending on the thickness of the joint itself (Figure 1 (b)). The crisis occurs because of the low shear bond capacity of the mortar-brick contact while the bricks remain undamaged. *Diagonal crack* (Figure 1 (c)) occurs if the principal tension stress induced by a combination of high shear and compressive force reaches the tensile strength of the wall. Diagonal crack develop in both mortar and brick. A wall *crushes* in compression when the generated stresses reach the masonry compressive strength. In this case, cracks are concentrated in the compressive zone (Figure 1 (d)). If a retrofitting grid is applied to the external surfaces of the wall, the failure mode may completely change. In fact, in this case the cracking phenomena could spread on the entire surface of the wall (Figure 1 (e)), allowing more energy dissipation before the wall crisis. However, the mentioned mode of failure takes place when the reinforcement is effectively applied, namely bond is well assured and the presence of the reinforcement significantly changes the behavior of the masonry. Thus the shear strength contribution must be properly considered as explained in the next section (reinforced approach); on the other hand the panel can damage in one of the modes (a), (b) and (c) if the masonry and the reinforcement work independently; so the shear strength of the two layers must be considered as the sum of two contributions (un-reinforced approach).

1.2 Codes and scientific publications background

From the analytical point of view, codes and scientific publication provide approaches for obtaining the in-plane shear strength of unreinforced and reinforced masonry walls ([1]-[11]). Formulations for predicting the reinforced masonry shear capacity are more or less similar in all available codes. The case of unreinforced masonry is analyzed on the basis of different equations referring to the possible failure modes, e.g. in [1]-[6] . The principle of minimum total potential energy affirms that the difference between the total energy of deformation and the work done by the external forces is minimum in correspondence with the solution of the elastic problem. The mechanism that really happens is the safest energy failure mode, which corresponds to a minimum value of shear strength, V_{eff}. As regards the reinforced masonry approach, in the hypothesis of a perfect bond between the different layers (can be natural due to friction or artificial due to transversal connectors), the masonry's contribution is provided by one single equation (e.g. in [3]-[4]-[7]-[8]-[9]-[10]-[11]). The aim is to model the change of behavior of the reinforced masonry with respect to the unreinforced masonry (distributed cracks). In both approaches, the contribution of the reinforcement (steel, FRP, GFRP, mortar + fibers) is summed to that of masonry (e.g. in [1]-[2]-[3]-[4]-[5]-[6]-[8]-[9]-[10]-[11]. The two approaches are schematically summarized in the following Eqs. (1), (2) and (3):

- Un-reinforced masonry approach:

$$V_{eff} = min\begin{cases} V_{sliding} \\ V_{diagonal\_crack} \\ V_{toe\_crush} \end{cases} \tag{1}$$

- Reinforced masonry approach:

$$V_{eff} = \propto f_{masonry}^{m} \; A_n + V_{reinforce} \tag{2}$$

$$V_{reinforce} = V_{fiber} + V_{matrix} \tag{3}$$

Where *m* most used values are 0.5 and 1.

2 ARTIFICIAL NEURAL NETWORK (ANN)

2.1 Introduction

Artificial neural network (ANN) is inspired by the architecture of human nervous system, which consists of a large number of neurons that are responsible for learning and decisions making. In fact, neural networks have been conceived as the computational structures that can "learn". All neurons are connected by numerous *synapses* and can work simultaneously. In order to understand a process or a phenomenon, the human neural network creates a matrix of *weight*. Each neuron provides a *bias* to the event and than checks it in order to create knowledge. The matrix can be adjusted by learning process. The procedure used to perform the learning process is called *learning algorithm* which is the function able to modify the synaptic weight of the network. When a stimulus is receipted by the brain, it goes in the neural network for interpretation by electrical impulse. The effectors covert the electrical signal generated by the neural net into the response as system outputs. Similarly, the ANN proposes a weight matrix of numerical value and a bias for each neuron in which different analytical formulas (*transformation* formula) are solved in order to create adjustments to the matrix itself. The input quantities are processed through successive layers of “neurons”. The input layer (with the number of neurons equal to the number of variables in the problem) and an output layer are always considered. A defined number of layers in between, so called “hidden” layers, are also provided. Commonly only one hidden layer is considered; however, when using two or more hidden layers a more efficient prediction is guaranteed.

2.2 Back-propagation neural network

A Back Neural Network (BNN) is composed of a number of neurons, connected by links, each associated with a numerical weight. Learning takes place by updating the weights. Some units are connected with the environment and serve as a unit of input or output. Each unit has a set of input connections that originates from other units and a level of activation. An algorithm is set to calculate the activation level following data inputs and the relative weights. After this calculation, the neuron sends the new level of activation along all output connections (Figure 2).

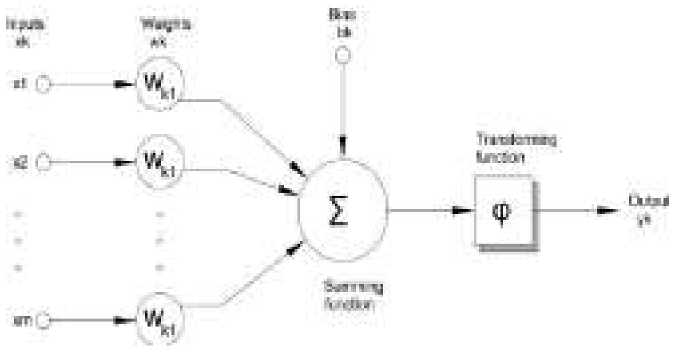


Figure 2: Back-propagation neural network model

The back propagation neural network has been described exhaustively in the literature, e.g. [12], [13], [14] and [15], and the fundamentals are only considered briefly in this paper. It is possible to distinguish a set of theoretically infinite connections (characterized by a weight numeric value), a finite number of adder (which combines the competitor input) and an activation function (which limits the amplitude of the output neuron) in a neural network process. This model also includes an external applied bias, called b_k, which can increase or decrease the input of the activation function. Considering an input vector of general variables x_1, x_2,…,x_m and the corresponding weight vector of the k-neurons, such as w_{k1}, w_{k2},…,w_{km}; the summing and the activation function are provided by Eq. (4) and (5) respectively.

$$u_k = \sum_{j=1}^{m} w_{kj}\, x_j \tag{4}$$

$$y_k = \varphi(u_k + b_k) \tag{5}$$

Where φ is the activation function and y_k is the output signal of the neuron. The presence of the bias b_k produces and affines transformation of the output u_k as shown by Eq. (6).

$$v_k = u_k + b_k \tag{6}$$

Where v_k is the transformed output of k-neuron. Eqs. (4) and (6) can be combined in Eq. (7) as follow:

$$v_k = \sum_{j=0}^{m} w_{kj}\, x_j \tag{7}$$

Where new synapse and new weight are added as explained in Eq. (8) and (9).

$$x_0 = +1 \tag{8}$$

$$w_{k0} = b_k \tag{9}$$

Consequently, the activation function can be reported by Eq. (10).

$$y_k = \varphi(v_k) \tag{10}$$

This function can expressed in different form but the most used one is the sigmoidal (S-shape). An example of logistic function is proposed in Eq. (11).

$$\varphi(v) = \frac{a}{1 + b \times e^{(-cv}} + d \tag{11}$$

Where *b* and *c* are the slope parameter of the sigmoidal. As the human brain consists of millions of neurons that are interconnected by synapses, NN are formed from large numbers of simulated neurons, connected to each other in a manner similar to brain neurons. As in the human brain, the strength of neuron inter-connections may change (or be changed by the learning algorithm) in response to a presented stimulus or an obtained output, which enables the network to “learn”. In this paper BNN is used in order to find the relationship between mechanical and geometrical parameters involved in the phenomena of shear response of FRCM retrofitted masonry panel, and to evaluate the α coefficient reported in Eq. (2) being *m* equal to 1. For this purpose, diagonal shear laboratory tests are collected and described in the next section. The goal is to create the input database of the ANN procedure.

2.3 Neural network database

Results of diagonal compressive test, performed according to the standards reported in [16], and available in the scientific literature are listed in this section. FRM technique is tested as shear reinforcement of masonry panels. The Table 1 presents the geometrical and mechanical characteristics of the specimens utilized as an initial database for the BNN procedure; the shear capacity obtained from experimental investigations, $V_{max,tot}$, is also reported. Matrix of different materials including cement, lime and stone dust recycled by the manufacturing of the stone itself are arranged in the database in order to obtain an analytical model of general validity for existing masonry constructions, including historic ones.

Table 1 - BNN initial database.

Ref.	n°	SAMPLE NAME	GEOMETRY			MECHANICAL PROPERTY			$V_{max,tot}$ [kN]
			$A_{n,fiber}$ [mm^2]	$A_{n,matrix}$ [mm^2]	$A_{n,masonry}$ [mm^2]	$f_{c,masonry}$ [MPa]	$f_{c,matrix}$ [MPa]	$f_{t,fiber}$ [MPa]	
[17]	1	S1 - FB8 - 1	400,0	103200,0	129000,0	6,92	8,00	350,00	93,97
	2	S1 - FB8 - 2	400,0	102400,0	128000,0	6,92	8,00	350,00	109,88
	3	S1 - FB13 - 1	400,0	103200,0	129000,0	6,92	13,00	350,00	96,10
	4	S1 - FB13 - 2	400,0	103200,0	129000,0	6,92	13,00	350,00	97,44
	5	S1 - FBSC - 1	400,0	103200,0	129000,0	6,92	8,00	350,00	100,90
	6	S1 - FBSC - 2	400,0	103200,0	129000,0	6,92	8,00	350,00	101,61
	7	S1 - FBML - 1	400,0	103200,0	129000,0	6,92	6,01	350,00	95,39
	8	S1 - FBML - 2	380,0	98400,0	123000,0	6,92	6,01	350,00	94,33
	9	D1 - FB8 - 1	400,0	104000,0	195000,0	6,92	8,00	350,00	100,20
	10	D1 - FB8 - 2	400,0	104000,0	195000,0	6,92	8,00	350,00	100,20
	11	D1 - FRCM - A1	8,7	26000,0	195000,0	6,92	15,00	2000,00	100,20
	12	D1 - FRCM - A2	8,7	26000,0	195000,0	6,92	15,00	2000,00	102,32
	13	D1 - FRCM - B1	7,3	52000,0	195000,0	6,92	20,00	5800,00	101,26
	14	S2 - FB8 - 1	620,0	160800,0	241200,0	6,92	8,00	350,00	148,99
	15	S2 - FB8 - 2	620,0	160000,0	240000,0	6,92	8,00	350,00	155,21

	16	S2 - FRCM - A1	13,4	40000,0	300000,0	6,92	15,00	2000,00	168,01
	17	S2 - FRCM - A2	13,3	39800,0	298500,0	6,92	15,00	2000,00	176,99
	18	D2 - FB8 - 1	620,0	162400,0	426300,0	6,92	8,00	350,00	157,26
	19	D2 - FB8 - 2	620,0	202000,0	404000,0	6,92	8,00	350,00	172,46
	20	D2 - FRCM - A1	13,4	80400,0	462300,0	6,92	15,00	2000,00	186,96
	21	D2 - FRCM - A2	13,4	80400,0	462300,0	6,92	15,00	2000,00	189,08
[18]	22	MD - 1A- F33S	273,6	69600,0	290000,0	11,50	7,80	897,37	275,33
	23	MD - 2A- F33S	273,6	69600,0	290000,0	11,50	7,80	897,37	262,85
	24	MD - 1A- F66S	136,8	69600,0	290000,0	11,50	7,80	963,16	263,38
	25	MD - 2A- F66S	136,8	69600,0	290000,0	11,50	7,80	963,16	296,83
	26	MD - 1A- F99S	91,2	69600,0	290000,0	11,50	7,80	586,84	299,07
	27	MD - 2A- F99S	91,2	69600,0	290000,0	11,50	7,80	586,84	283,08
	28	MD - 1C - F33S	273,6	69600,0	290000,0	15,70	7,80	897,37	297,55
	29	MD - 2C - F33S	273,6	69600,0	290000,0	15,70	7,80	897,37	291,96
	30	MD - 1C - F66S	136,8	69600,0	290000,0	15,70	7,80	963,16	335,58
	31	MD - 2C - F66S	136,8	69600,0	290000,0	15,70	7,80	963,16	357,77
	32	MD - 1A- S150	314,2	69600,0	290000,0	11,50	7,80	540,00	229,50
	33	MD - 2A- S150	314,2	69600,0	290000,0	11,50	7,80	540,00	239,95
	34	MD - 1A- S200	339,3	69600,0	290000,0	11,50	7,80	540,00	287,63
	35	MD - 2A- S200	339,3	69600,0	290000,0	11,50	7,80	540,00	281,41
[19]	36	MT - 1A - F33S	273,6	69600,0	440800,0	11,50	7,80	897,37	338,58
	37	MT - 2A - F33S	273,6	69600,0	440800,0	11,50	7,80	897,37	340,80
	38	MT - 1A - F66S	136,8	69600,0	440800,0	11,50	7,80	963,16	375,03
	39	MT - 2A - F66S	136,8	69600,0	440800,0	11,50	7,80	963,16	307,24
	40	MT - 1A - F66D	273,6	69600,0	440800,0	11,50	7,80	760,53	387,68
	41	MT - 2A - F66D	273,6	69600,0	440800,0	11,50	7,80	760,53	406,85
	42	MT - 1A - F99D	182,4	69600,0	440800,0	11,50	7,80	797,37	323,42
	43	MT - 2A - F99D	182,4	69600,0	440800,0	11,50	7,80	797,37	293,04
	44	MT - 1B - F99D	182,4	69600,0	440800,0	11,50	7,80	797,37	292,69
	45	MT - 2B - F99D	182,4	69600,0	440800,0	11,50	7,80	797,37	223,23
	46	MT - 1A - S150	314,2	69600,0	440800,0	11,50	7,80	540,00	352,15
	47	MT - 2A - S150	314,2	69600,0	440800,0	11,50	7,80	540,00	285,76
[20]	48	MP - 1A - F33S	273,6	69600,0	464000,0	11,50	7,80	897,37	274,36
	49	MP - 2A - F33S	273,6	69600,0	464000,0	11,50	7,80	897,37	254,54
	50	MP - 1A - F66S	136,8	69600,0	464000,0	11,50	7,80	963,16	234,68
	51	MP - 2A - F66S	136,8	69600,0	464000,0	11,50	7,80	963,16	259,05
	52	MP - 1A - F66D	273,6	69600,0	464000,0	11,50	7,80	760,53	290,39
	53	MP - 2A - F66D	273,6	69600,0	464000,0	11,50	7,80	760,53	281,60
	54	MP - 1B - F66S	136,8	69600,0	464000,0	11,50	7,80	963,16	260,82
	55	MP - 2B - F66S	136,8	69600,0	464000,0	11,50	7,80	963,16	277,93
[21]	56	1 ply - 1	122,0	24400,0	81290,0	24,00	17,20	802,00	108,82
	57	1 ply - 2	122,0	24400,0	81290,0	24,00	17,20	802,00	133,22
	58	1 ply - 3	122,0	24400,0	81290,0	24,00	17,20	802,00	118,02
[22]	59	CD-07-U-IP	277,0	72000,0	684000,0	2,00	21,36	530,00	235,75
	60	CD-11-S-IP	277,0	72000,0	456000,0	0,04	21,36	530,00	79,27

	61	CD-12-P-IP	277,0	72000,0	864000,0	2,00	21,36	530,00	152,59
	62	CD-13-P-IP	277,0	72000,0	768000,0	2,00	21,36	530,00	190,35
	63	CD-14-P-IP	277,0	72000,0	768000,0	2,00	21,36	530,00	144,32
[23]	64	PM10	8,8	18680,0	49035,0	28,57	37,89	3400,00	94,26
	65	PM11	8,8	18680,0	49035,0	28,57	37,89	3400,00	84,71
[24]	66	P1GG	106,0	30000,0	312500,0	2,34	16,10	1035,00	138,29
	67	P2GG	106,0	30000,0	312500,0	2,34	16,10	1035,00	126,88
[25]	68	#04	10,5	45600,0	456000,0	1,31	38,00	4800,00	161,88
	69	#05	11,1	48000,0	480000,0	1,31	38,00	4800,00	159,06
	70	#06	10,6	45920,0	445424,0	1,31	38,00	4800,00	154,90
	71	#07	10,7	46120,0	466965,0	1,31	38,00	4800,00	141,87
	72	#08	10,7	46200,0	453915,0	1,31	38,00	4800,00	113,89
	73	#09	10,7	46120,0	447364,0	1,31	38,00	4800,00	141,95
[26]	74	RFDSP - 9	184,0	45600,0	220400,0	3,72	49,03	850,91	149,85
	75	RFDSP - 15	184,0	45600,0	133000,0	3,72	49,03	850,91	104,62

Where: A_n = the net area equal to the transversal cross-section (mm^2), f_c is the compressive strength (MPa), $V_{max,tot}$ is the shear strength registered for each sample (kN) corresponding to to V_{eff} in Eq. (2).

2.4 Model development

The first step of model development is the "selecting", which consists of a careful review of existing data (creation of the database, as reported in the previous section). A number of 75 samples are considered, including different materials and geometries, all subjected to diagonal compressive test. The "modelling" phase starts with the identification of the input and target parameter:

- First input parameter, β, expressed in Eq. (12).
- Second input parameter, γ, expressed in Eq. (with y_k in Eq. (11).

$$\beta = \frac{f_{t,fiber} \times A_{n,fiber}}{f_{t,masonry} \times A_{n,masonry}} \tag{12}$$

Where:

$$f_{t,masonry} = 0{,}7\sqrt{f_{c,masonry}} \tag{13}$$

$$\gamma = \frac{f_{c,matrix}}{f_{c,masonry}} \tag{14}$$

The parameter β correlates the fibers tensile strength with the masonry tensile strength while the parameter γ is the compressive strength ratio of the inorganic matrix and the masonry. Experimental values of the targets have been calculated from the inverse formula of Eq. (2) where α is the only unknown. BNN method was adopted following instructions reported in section 4.1. The analytical relationships obtained by the procedure are formulated in Eqs. (15) and (16).

$$\alpha = \frac{0{,}363}{1 + e^{-v}} \tag{15}$$

Where:

$$v = -0{,}52 + 1{,}36\,\beta + 0{,}05\,\gamma \tag{16}$$

The obtained Gaussian curve is shown in Figure 3. The normal distribution of frequency highlights the wellness of prediction of the proposed model. Horizontal axis reports the ratio between experimental e analytical value of the target α (which coincides with the ratio of the experimental and analytical value of the maximum shear force, V_{eff}) while the vertical axis presents the frequency of repetition for each value. As evident, the average (μ) and the mode (Mo) values are equal to 1; while the median (Me) value is equal to 0.94 with a standard deviation σ of 0.324. The first considerations on the validity of the model can be done on the basis of statistical parameters, as RRMSE (Relative Root Mean Square Error), MAE (Mean Absolute Error) and MAPE (Mean Absolute Percentage Error), expressed by Eq. (17), (18) and (19) respectively.

$$RRMSE = \frac{1}{n}\sqrt{\sum_{i=1}^{n}\left(\frac{y_i - \hat{y}_i}{y_i}\right)^2} \times 100 = 4{,}00\% \tag{17}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i| = 37{,}40kN \tag{18}$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right| = 24{,}7\% \tag{19}$$

Where: n = the number of samples in the input database, i = the general sample, y_i = the experimental value, $\hat{y}_i$ = the theoretical value.

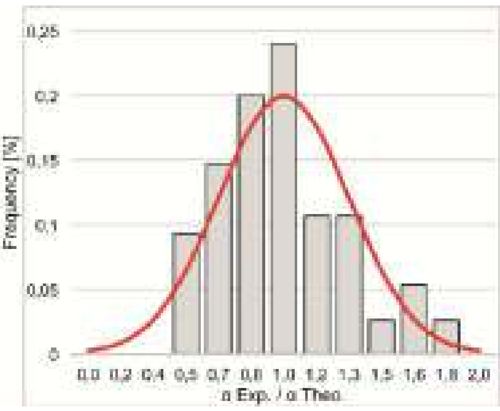


Figure 3: Histograms and normal distribution curve for the proposed model

The RRMSE is commonly used to measure the difference between the predicted and actual value in percentage. In Eq. (17) RRMSE results equal to 4%, which indicate the excellent power of prediction of the model. The MAE provide an estimation of the scatter between experimental and predicted results; in Eq. (18) MAE is equal to 37.40 kN, which compared with the experimental values of the ultimate shear force reported in Table 1 is very low. The MAPE describes the behavior of the model by valuing its trend estimation (in other words, if the anomalies in the prediction are not significant with respect the good estimations). In Eq. (19) MAPE is equal to 24.70%, which means the trend estimation is sufficiently precise.

2.5 Model evaluation and parametric study

In order to provide a more detailed valuation of the ANN model, the Eq. (17)-(19) are not sufficient. In fact, they give indications about the accuracy of the model or rather the absence of systematic errors in the prediction. The greater is the accuracy; the closer is the average value to the theoretical value. On the other hand, the mentioned parameters do not give information about the precision of the model. The precision is the variance of the theoretical values with respect to the average value of the experimental data. Accuracy and precision may be both analyzed in the Gaussian curve in Figure 3 (red line); where the accuracy corresponds to the kurtosis K (or flattening) of the curve and the precision corresponds to the symmetry (or skewness) of the curve and to the distance of its symmetry axis to the value 1 (experimental over theoretical). The kurtosis of the curve is calculated in Eq. (20). If the kurtosis coefficient K is:

- >0 the curve is defined leptokurtic , i.e. more "pointed" of a normal;
- <0 the curve is defined platykurtic , that is "flatter " than a normal;
- =0 the curve is defined normocurtica , i.e. "flat" as a normal.

$$K = \frac{\sum_{i=1}^{n} \left(\frac{x_i - \mu}{\sigma} \right)^4}{n} = 3{,}12 \tag{20}$$

The precision of the frequency curve can be evaluated with the asymmetry of mode (as1) and with the first and the second asymmetry Pearson coefficients (as2 and as3) calculated in Eq. (21), (22) and (23) respectively.

$$as1 = \frac{\mu - Mo}{\sigma} = 0 \tag{21}$$

$$as2 = \frac{3(\mu - Mo)}{\sigma} = 0 \tag{22}$$

$$as3 = \frac{3(\mu - Me)}{\sigma} = 0{,}54 \tag{23}$$

The compromise of accuracy and precision of the proposed model is also graphically explained in the box plotted in Figure 4. The graph represents the frequency of the predictions in quartiles or rather four intervals equally populated by values with the same frequency. The illustration consists in a rectangle (the “box”) divided in two parts and two external segments. The box is individuated between the first and the third quartile (Q1 and Q3 respectively) and it is internally divided by the median (Me). The segments are delimited by the minimum and the maximum value (Q2 and Q4 respectively). The difference of Q1 and Q2 is called Inter Quartile Range (IQR). All the box plot parameters are listed in Table 2.

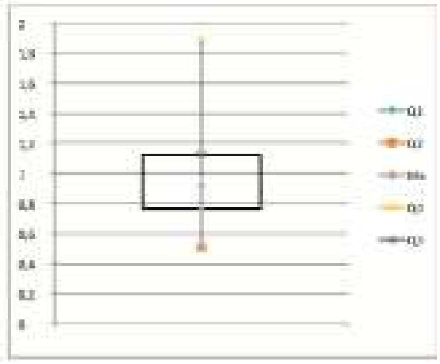


Figure 4: Box plot for the proposed model

Table 2: Box plot data.

Q1	0.77
Q2	0.52
Q3	1.13
Q4	1.89
Me	0.94
IQR	0,36

In Figure 4 it is possible to evaluate the accuracy of the model by comparing the dimension of the box (equal to IQR) to the dimension of the domain; the precision of the model is measured by the position of the box in the domain and the position of the Me value in the box. The box represents the range in which the 50% of the predictions are restrained and it is equal to 26.27% of the entire domain (50% of the prediction are in a small range around the perfect prediction). The value of Me is very close to the medium value of the box (equal to 0.95), which means that the average value is in the box range and it is enough close to the perfect prediction (=1). In other words, the closer is the box to the value 1, the more precise is the model and the closer is the Me to the symmetric axis of the box, the more precise is the model. The results of a parametric study are reported in Figure 5 and Figure 6, aiming to investigate the effectiveness of the model in predicting the behavior of FRM reinforced masonry panels. In Figure 5 the shear strength of a masonry panel is plotted as a function of the ratio between the tensile strength of fibers and that of the masonry, varying the ratio between the net area of the fibers and that of the masonry panel. Three different ratios of net areas are considered, namely 0.15, 0.25 and 0.4. As expected, if a specimen with fixed materials (fibers and masonry) is considered, the maximum resistant shear force V_{max} increases with the net area of the fibers. Similarly, if a specimen with fixed geometry (fibers and masonry) is considered, the maximum resistant shear force V_{max} increases with the tensile strength of the fibers. The shear capacity increases linearly with the ratio $f_{t,fiber}/f_{t,masonry}$ at a low value of the net area ratio (0.15). The linear trend is lost with a significant increment of the net area of the fibers. In fact, at high values of fibers amount the shear capacity remains constant over certain values of the $f_{t,fiber}/f_{t,masonry}$ ratio. The effect of the ratio between the compressive strength of the matrix and that of the masonry on the shear strength can be analyzed in Figure 6. If a masonry panel with fixed geometry (net area) is considered, the value of V_{max} increases with the compressive strength of the matrix. If a specimen with fixed material proprieties (compressive strength) is considered, the V_{max} decreases with increasing the masonry net area. It is reasonable to consider that the greater is the thickness of the sample the lower is the probability that cracks form in the masonry.

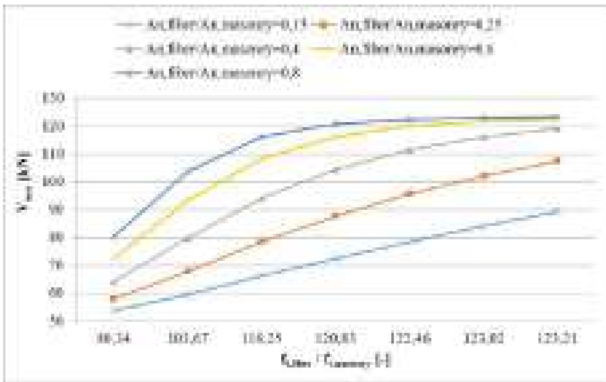


Figure 5: Effect of the net areas of fibers and masonry panel ratio and tensile strength of fibers and masonry panel ratio on the shear strength contribution of the reinforced panel

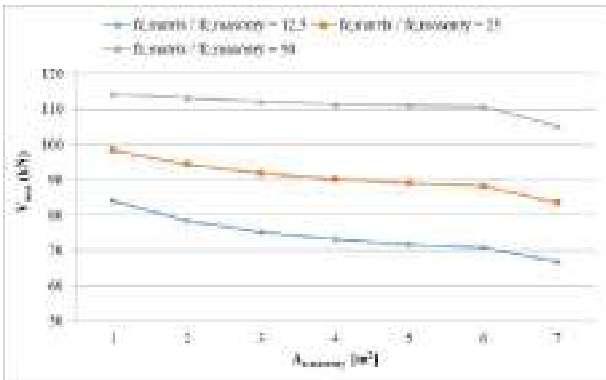


Figure 6: Effect of the compressive strength of the matrix and the masonry panel ratio on the shear strength contribution of the reinforced panel

3 CONCLUSION

An analytical model for predicting the shear strength of FRM masonry, using the ANN approach, is developed in this paper. Experimental campaigns related to the topic are also provided. Samples strengthened with FRM system and subjected to diagonal compressive test were selected. Among them, there was a great diversity in terms of the type of masonry (material and texture) and of the type of reinforcement, referring to both fibers (glass, carbon, steel, basalt, PBO, etc.) and matrix (cement, lime, recycled stone). The utilized database and the subsequent analysis allowed to provide a model valid for masonry constructions, including historic ones. The investigated variables were multiple and synthesizable in geometry and mechanical proprieties of the layers (masonry, matrix and grid). The model was generated using ANN process, i.e. an algorithm that can extract information from databases through the construction of a neural network similarly to the human central nervous system. Despite the great diversity of input parameters, the model present good precision and accuracy in predicting the shear strength of the FRM masonry. The robustness and sensitivity of the model were evaluated through a parametric study. The model seems to work in the predictable way describing the cooperation of the layers involved (masonry, matrix and grid) and the consequent change of behavior of the masonry panel in coherence with the observed phenomena.

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AUTHOR INDEX

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Chapter I General Principles- Professional Responsibilities
Chapter II New Structures and Historic Environment Relationship
Chapter III The Problems Affecting the Historic Environment
Chapter IV Factors Affecting New Design in Historic Environment
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Chapter VI Construction Methods and Materials of New Design in Historic Environment

The contributions in this proceedings book may be useful for professionals and researchers engaged in the problems of new designs in historical context.

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