



Félix Candela, El Altillo church, Mexico city.



Félix Candela, restaurant Los Manantiales in Xochimilco, Mexico city.

Message of the President of ISCARSAH Görün Arun

Dear Friends and Colleagues,

It is a great privilege for me to write my first message to you as president of our International Scientific Committee in the ISCARSAH Newsletter edited by Vice President Maya Segarra Lagunes. I am honored to be following in the 18-year line of my distinguished predecessors in the presidency, beginning with Giorgio Croci. I would like to thank my immediate predecessor, Stephen Kelley who has been an outstanding leader of our Committee for six years and his team especially to the members who departed: Lyne Fontaine, Debra Laefer and Peter Elliot. I am grateful that Stephen Kelley and Maria Margarita Segarra Lagunes continue to be vice-presidents, and Khalid El Harrouni, In-Souk Cho and Marcella Hurtado volunteered to be vice presidents and secretary general of this term's ISCARSAH bureau.

In 2014, we made two meetings: in Mexico City on October 14, 2014 during SAHC2014 Conference and in Florence on November 13, 2014 during ICOMOS General Assembly. The meeting in Mexico City was in Kristal Grand Reforma, 12 members attended the meeting and four members who were not able to journey to Mexico City could follow the first half of the meeting through the internet with the hard work of Prof. Ahmet Türer. During the meeting Don Friedman took on the responsibility to set up our new website for the previous domain had expired. The technical visit to the four shell buildings of Candela, Xochimilco Los Manantiales Restaurant, Rayos Cósmicos Pavillion, El Altillo Church and Medalla Milagrosa Church was very interesting. We are thankful to Prof. Juan Gerardo Oliva Salinas who organized this trip and aired a film about Candela and his work on the way.

The meeting during the ICOMOS General Assembly in Florence was in Villa Vittoria; 19 members and 3 guests attended the meeting. During the meeting, the changes of the ISCARSAH Statutes, the voting rights of Honorary Members, composition of the ISCARSAH Bureau and responsibilities of the Bureau were approved. Valentin Feodorov (Romania) is upgraded as expert member. And the applications of becoming a member of ISCARSAH, three expert members: Prof. Lu Zhou (China), Prof. Camilla Mileto (Spain), Prof. Fernando Vegas López-Manzanares (Spain); 5 associate members: Ahmed Attia (Algeria), Alessia Cascardi (Italy), Vasilius Sarhosis (UK), Hamidreza Taravat Najafabadi (Iran), Nicola Tarque Ruiz (Peru) and two corresponding members: Prof. Rosario Ceravolo (Italy),

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Prof. Zhu Quang Ya (China), were happily welcomed. These new members are also listed in the recent list-serve. In the last part of the meeting ISC on Timber Structures joined and Prof. Dina D'Ayala introduced the COST Action. The details of these meetings were released in the form of meeting minutes.

The 2015 ISCARSAH meeting is planned in July 2015 in Istanbul as part of RE-Cond'15- Re-Evaluating Contemporary Designs in Historical Context. Several ISCARSAH members took part in the scientific committee and many others sent their abstracts to contribute the Conference seeking to re-evaluate the attitudes to existing environments via discussing new architectural, structural and urban projects built or to be built in natural and/or cultural and/ or historical contexts, the way to participate to the space and harmonize the new projects in existing elements and resources and meet the contemporary requirements.

I'm sure many of us will benefit the contributions to this issue.

Sincerely,

E. Görün Arun

ISCARSAH President



Félix Candela, Rayos Cósmicos Pavillion, Mexico city.

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Analysis and Restoration of Structures of
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Félix Candela, church la Medalla milagrosa, Mexico city.

Rehabilitación estructural del antiguo templo de San Agustín en la Ciudad de México

Abraham R. Sánchez Ramírez - Roberto Meli

Instituto de Ingeniería, Universidad Nacional Autónoma de México (UNAM)

Breve nota histórica

El antiguo templo de San Agustín formaba parte del conjunto conventual establecido, desde 1541, en la Ciudad de México por los frailes agustinos.

La primera construcción formal fue realizada por Claudio de Arciniega entre 1561 y 1590 y fue destruida por un fuerte incendio que afectó toda la nave del templo y parte del convento.

El gran templo barroco que todavía subsiste, aunque con importantes modificaciones, fue iniciado en 1677, sobre los cimientos del anterior, y fue terminado en 1692. Se trata de una de las mejores joyas de la arquitectura religiosa de la época virreinal, que destacaba por la gran altura de su nave, por la riqueza de sus portadas y del retablo atrás del altar mayor, así como de la sillería del coro y de sus esculturas. En 1714 se construyó la Capilla de la Tercera Orden, adosada al lado suroeste del templo.

Con la llegada de la República, el conjunto conventual fue secularizado y, en 1862, fue severamente modificado al demolerse las torres y al sobreponer a la fachada barroca original una nueva fachada neoclásica, con el propósito de instalar ahí la Biblioteca Nacional que fue inaugurada en 1862. El conjunto fue afectado desde sus inicios por los hundimientos y tuvo que ser objeto de diversas restauraciones, la más importante en 1956.

En 1979, la Biblioteca Nacional fue trasladada a la Ciudad Universitaria. Desde entonces el edificio ya no ha tenido un uso continuo y ha seguido sufriendo los efectos de los hundimientos.

En 1983 se realizó otra etapa de restauración, lo que no frenó los hundimientos ni el consiguiente progreso de los daños.

La intervención geotécnica reciente

El hundimiento de los edificios virreinales del centro histórico de la



Vista del templo y la capilla a finales de la primera mitad del siglo XIX.



Vista del templo y la capilla en la primera década del siglo XX.

ciudad de México fue debido, en un principio, al peso de los edificios y a la desecación natural de los estratos saturados, pero desde la segunda mitad del siglo pasado, es consecuencia principalmente de la sobreexplotación de los acuíferos subterráneos.

Los cimientos de la mayoría de estas construcciones quedaron desplantados, parcialmente, sobre

suelos que habían sido preconsolidados por el peso edificios previos, y en otras partes sobre suelos que eran más deformables, porque no habían tenido cargas significativas previas.

Esta ha sido la causa principal de los asentamientos diferenciales que ocasionan la distorsión de los edificios, acompañada de severos agrietamientos en muros y bó-

vedas, así como de importantes desplomos de sus elementos portantes, que son las columnas y muros.

Tanto el templo de San Agustín, como la capilla se encontraban en un estado de daño muy avanzado, debido principalmente a los fuertes asentamientos diferenciales que se fueron acumulando a lo largo del tiempo. Estos daños fueron acentuados por el deterioro de los materiales y por los efectos de las filtraciones de agua por las grietas que se habían quedado abiertas sobre todo en las bóvedas y en la cúpula.

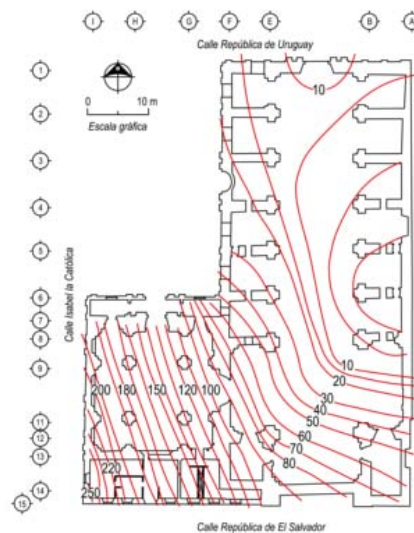
Las curvas de nivel del piso de feligresía del conjunto permiten apreciar un importante asentamiento hacia el suroeste que se acentúa en la capilla.

Llama la atención la diferencia de nivel de 2.5 m entre la base de la pilastra del centro del templo y la de la esquina suroeste de la capilla. También llama la atención que la capilla se haya hundido mucho más que el templo, probablemente porque se construyó y se ligó a este, mucho tiempo después, cuando éste último había ya experimentado buena parte de su hundimiento. Asimismo, hay que tener presente que el templo se erigió sobre un suelo que había sido previamente consolidado con el peso de las construcciones previas, mientras que la capilla se desplantó sobre un terreno que no había estado sometido a soportar antes cargas de consideración.

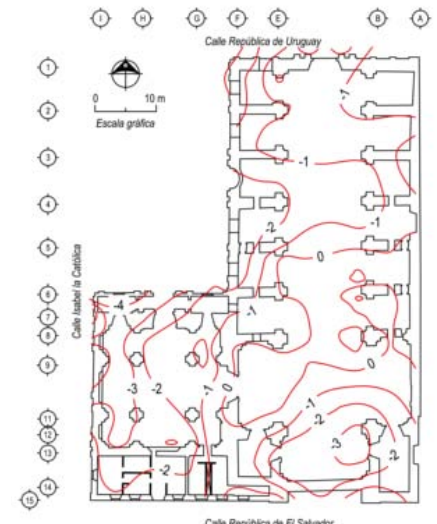
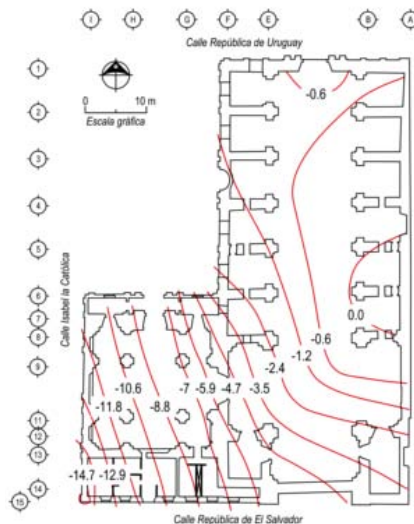
En 1999, la UNAM contrató los servicios de una empresa de ingeniería geotécnica para corregir los patrones de hundimientos que presentaban el templo y su capilla anexa. A lo largo de 13 años, se llevaron a cabo cuatro campañas de endurecimiento del subsuelo, en las zonas donde éste era más blando, con el fin de frenar su velocidad de descenso y tratar de igualarla a la de las zonas más duras. Para ello se empleó la técnica de las intrusiones mediante la inyección de mortero, la misma que se había aplicado para controlar los asentamientos diferenciales de la Catedral de México.

De esta manera logró reducir drásticamente el crecimiento de los asentamientos diferenciales. Como ejemplo, la diferencia de hundimiento entre los dos puntos más críticos, que crecía a razón de 14 mm/año antes de la interven-

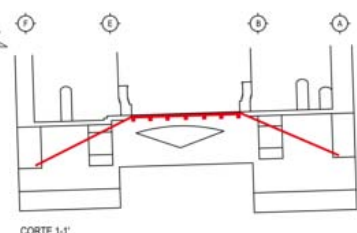
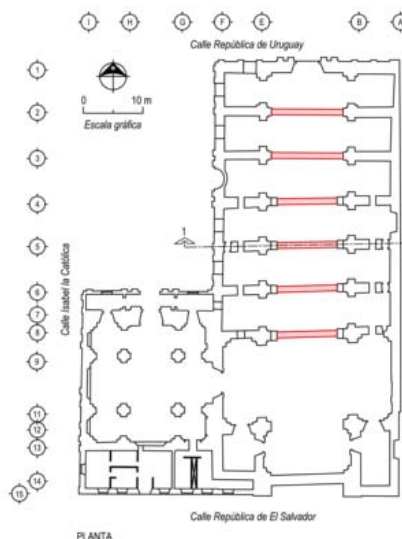
ción en el suelo, ha crecido a sólo 3 mm/año desde que finalizaron los trabajos. En paralelo a última etapa de endurecimiento selectivo del suelo, también se reforzó la subestructura colocando tensores a base de barras de refuerzo en seis de las contratraves transversales de la cimentación, para rigidizarlas y para que se opusieran a la deformación cóncava generada por los asentamientos diferenciales. Al finalizar la intervención geotécnica, las autoridades universitarias consideraron que estaban dadas las premisas para proceder a su rehabilitación estructural que le permitiese, después, acondicionarlo para constituir un centro de consulta virtual y de eventos culturales diversos.



Curvas de igual asentamiento diferencial del piso de feligresía (en cm).



Curvas de igual velocidad de hundimiento diferencial registradas antes y después del mejoramiento del suelo, expresadas en mm/año.



Tensores para rigidizar las contratraves transversales del templo.

Para ello, se encargó al Grupo de Ingeniería Estructural de Edificios Históricos del Instituto de Ingeniería, la elaboración del proyecto de rehabilitación estructural y la supervisión técnica de la posterior ejecución de dicho proyecto.

También se asignó a una firma de arquitectos el proyecto del reacondicionamiento arquitectónico del conjunto.

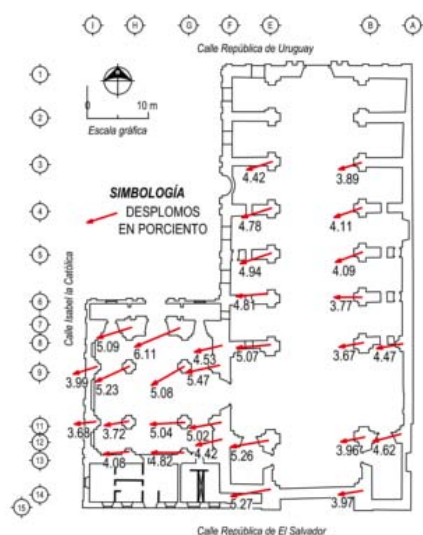
Los trabajos dieron comienzo en 2013 y están previstos para terminar en junio de 2015.

Estado de daño y diagnóstico estructural

El problema más serio desde el punto de vista estructural es la inclinación de las columnas y los



Fracturas y deterioro de mampostería en bóveda y arcos.



Desplomos de las cabezas de pilastras y muros.



Grietas en muros y columnas.



muros de soporte, la que sobrepasa 4% de su altura, en algunas columnas del templo y 5 % en diversas columnas de la capilla. Hay que notar, además, que las columnas del lado poniente del templo están más inclinadas que las del oriente, lo que da lugar a la abertura del claro de las bóvedas y arcos de la nave, con su consiguiente agrietamiento. Destacan también, el fracturamiento de las dovelas de los arcos del techo del templo y de la capilla, sobre todo en sus arranques y en la clave, así como la pérdida de curvatura de los mismos elementos y la pérdida de mortero en las pilastras y en los muros de apoyo.

Las distorsiones de los dos edificios por los asentamientos diferen-

ciales de la cimentación produjeron grandes grietas en columnas y muros.

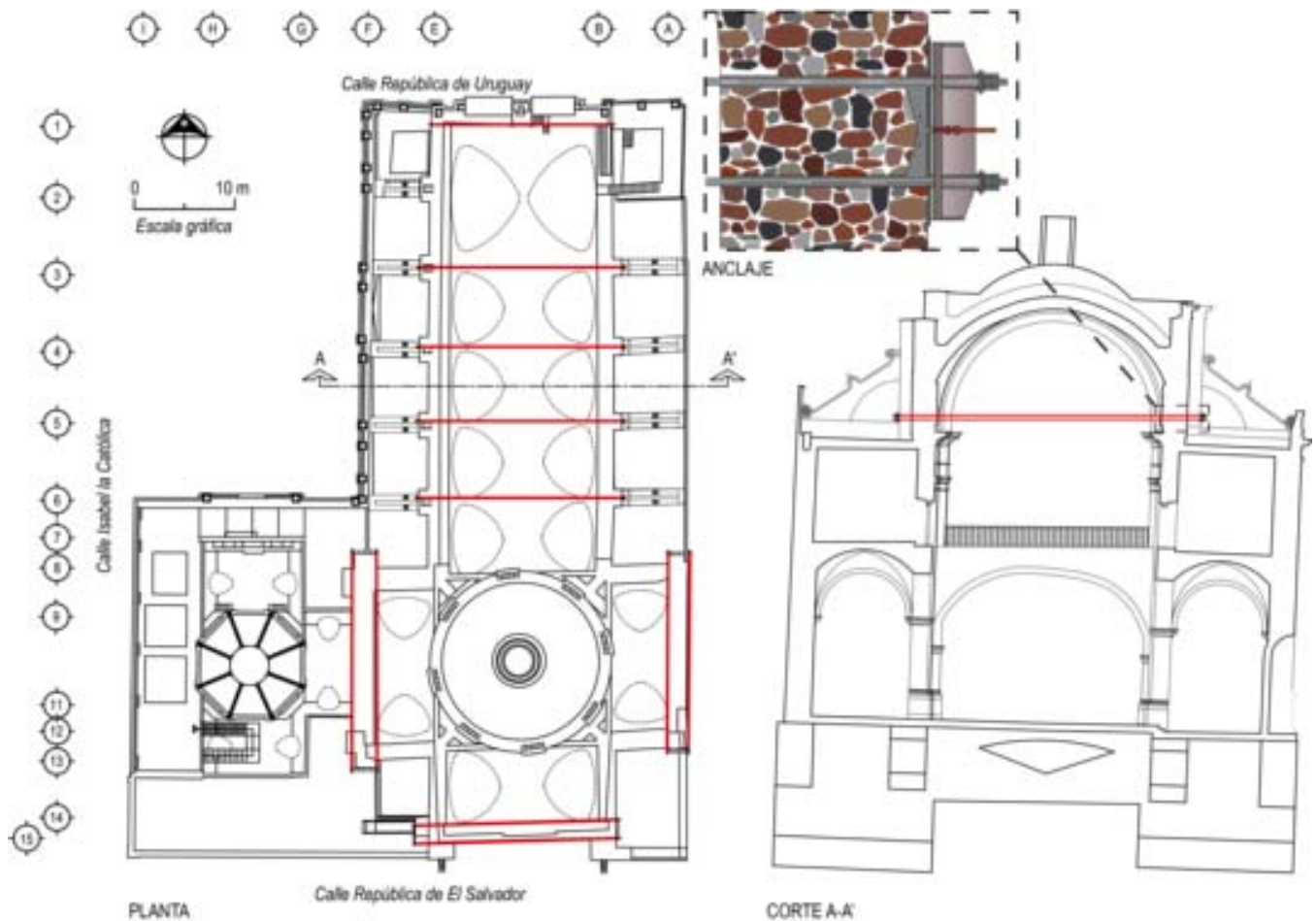
El mayor hundimiento de la capilla respecto al templo llevó al desprendimiento de la primera mediante una ancha grieta en sus bóvedas y muros, en la unión entre los dos edificios.

Numerosos son los daños locales que se identificaron en otros elementos como arcos botareles, cúpula y lunetos.

Los estudios para definir las características reales de los elementos y los materiales de la estructura se basaron en calas y en pruebas de laboratorio, incorporando también resultados obtenidos en los materiales de otros templos de la misma época que habían sido estudiados en proyectos previos de

restauración. Se realizaron análisis en modelos de elementos finitos ante la acción de las fuerzas gravitacionales y de los asentamientos diferenciales. Los resultados indicaron que los esfuerzos en los materiales estaban todavía dentro de límites aceptables, cuando se consideraba que los elementos y las secciones críticas estaban en un estado sano, pero que distaban de estarlo cuando se toman en cuenta los efectos de los daños y el deterioro de la estructura interna de los elementos.

A consecuencia de lo anterior, se diseñó un proyecto de rehabilitación que condujera a la estructura a trabajar en la forma que había sido concebida originalmente, eliminando o reduciendo al mínimo posible los efectos de los



Tensores para restringir la apertura de los arcos.

daños y dislocaciones que habían ocasionado los hundimientos.

La rehabilitación estructural en curso

Los trabajos de rehabilitación estructural comenzaron con la implementación de seis pares de tensores en los arranques de los arcos transversales de la bóveda que cubre la nave principal con el fin de restringir su tendencia a abrirse, debida al mayor asentamiento del lado poniente.

Posteriormente, se instaló una cerrada red de andamios y sobre ella se colocó una plataforma de trabajo a una altura de casi 20 m, a todo lo largo y ancho de la nave, lo que permitió el acceso al intradós de la techumbre, para consolidar la bóveda, restaurar las alfardas y dinteles de ventanas y, sobre todo, para realizar la sustitución de las dovelas fracturadas de los cinco arcos transversales y de los cuatro del crucero.

Ha sido esta última la parte más laboriosa y más delicada de la intervención. Se colocaron yugos de



Plataforma de trabajo y andamiaje para la restauración de los arcos y bóveda.

acero para detener los tramos de arco cercanos a la clave y así poder retirar las piezas fracturadas que componían las dovelas y sustituirlas por nuevas. Cada dovela está formada por dos piezas de aproximadamente 500

kg de peso cada una, que tuvieron que ser elevadas e insertadas en el hueco dejado por la pieza que se había retirado. Posteriormente, se inyectaban las juntas entre sillares. Al concluir el reemplazo de todas las piezas fracturadas se re-

tiraba el apoyo provisional.

En total se tendrán que sustituir alrededor de 250 piezas, lo que equivale a 125 dovelas completas. Otra actividad inicial fue la rehabilitación y refuerzo de muros del presbiterio y brazos del crucero. Para ello se aprovecharon unas vigas de concreto que se habían colocado en una restauración, para coser un conjunto de grandes grietas con trayectoria vertical que atravesaban el espesor completo de estos muros; dicho refuerzo se complementó con tensores anclados a los extremos del muro.

La rehabilitación de la cúpula y su tambor requirió, primero, la consolidación del tambor y pechinas, con inyecciones de lechada que también se hicieron en las diversas grietas que seguían los meridianos de la cúpula. La base de la cúpula se cinchó con bandas de resina reforzada con fibras de carbono para restringir su abertura por el coceo sobre sus elementos de apoyo.

Se rehabilitaron los muros con inyección de lechada en sus numerosas grietas verticales, se remampostearon las zonas más dañadas, se remplazaron dinteles y jambas de grandes ventanas, y se remplazó todo el chapeo de tezontle del muro testero. En las capillas laterales se reintegró la mampostería en los casquetes de sus bóvedas, debido a que en el pasado se les había abierto un hueco de sección cuadrada y, posteriormente, dichos huecos fueron cubiertos por un falso plafón.

Asimismo, se reintegró la mampostería en los muros divisorios, pues en alguna de las intervenciones se les había abierto un gran vano para permitir el paso a lo largo de las naves de capillas. Estos muros son fundamentales para la estabilidad de la bóveda que cubre la nave principal, ya que forman parte del sistema de contrarresto de ésta.

Respecto al coro, se tiene previsto consolidar su bóveda, sustituir las dovelas fracturadas de sus arcos y eliminar los pesados rellenos.

También se proveerá una sujeción eficaz a los altos y pesados florones de piedra que se encuentran sobre los remates del templo. Entre las diversas acciones efectuadas para subsanar los daños en la capilla, destacan:

- los cortes verticales en la mam-



Yugos metálicos para sostén temporal de los arcos y reposición de sillares en dovelas fracturadas.



Equipo de corte para abrir una junta de contrucción entre capilla y templo.

postería para generar una junta constructiva entre ambos edificios que permita la libre rotación de la capilla;

- la rehabilitación de muros, pilas-tras, bóvedas y arcos, así como de las fachadas que le fueron agregadas a la capilla a principios del siglo XX, ya que estas acusaban daños que evidenciaban su tendencia a separarse del cuerpo principal.

Comentarios finales

Las técnicas empleadas, tanto en las intervenciones en el subsuelo como en los cimientos y en la superestructura, habían sido aplicados ya en diversos edificios de la época con los mismos problemas, y se han venido afinando a partir de los resultados en cuanto a su viabilidad estructural y a la efectividad.

Es de esperarse que con esta rehabilitación, la seguridad estructural del conjunto permanezca

resguardada por largo tiempo. Sin embargo, es necesario que se lleve, además de un continuo mantenimiento del inmueble, un frecuente monitoreo para detectar a tiempo posibles señales de cambios en los patrones de comportamiento.

También es cierto que los problemas de los edificios históricos de la ciudad no van a terminar mientras no se reduzca drásticamente la sobreexplotación de los acuíferos que constituye el factor determinante de los problemas que afectan tanto éstas como otras construcciones en las zonas de los antiguos lagos de la cuenca de México.

Nota: Este artículo está adaptado del que los autores escribieron para ser publicado en la "Revista del Colegio de Ingenieros Civiles de México": Ingeniería Civil, n. 552, Año LXVI, Abril 2015.

Learning from *Sungnyemun*

Restoring to its original condition and implementing the state-of-the-art technologies

Cho In-Souk - ICOMOS Korea / ISCARSAH

Abstract

Sungnyemun – National Treasure No. 1 – was finally unveiled to the public in May 2013 after a long and highly anticipated restoration process after the unspeakably heinous arson attack of February 2008.

The restoration of historic gate was a major national project. It took five years, two months, and twenty days. The gate was restored using traditional materials and techniques, and more significantly the restoration process rendered an opportunity to strengthen disaster prevention systems.

First completed in 1398, *Sungnyemun* was used as the southern entrance to the royal capital of Seoul throughout the *Joseon* Dynasty (1392-1910).

It was built with an arch entrance in the center of Stone masonry base, and above that was built a wooden pavilion. Prior to the 2008 fire, it was the oldest wooden structure in the city of Seoul.

During the entire restoration process, the Cultural Heritage Administration of Republic of Korea maintained several basic principles: that as much salvaged materials be used as possible; that the gate structure be restored to how it appeared prior to the fire; and that some part of the city walls, which had been destroyed during the Japanese occupation, be rebuilt as much as possible.

Advanced system of technologies was implemented: a radio-frequency identification (RFID) system was installed to categorize the major damaged sections; advanced



Sungnyemun Gate before the 2008 fire.

3D laser scan technology was employed during the restoration. Of particular note is that masters of Korea's Intangible Cultural Heritages were mobilized en masse for the restoration.

Masters such as major carpenter, mason, painter, roof tile craftsman, roofer, blacksmith, as well as their apprentices, put forth all their effort during the restoration work.

In the history of Korea's Cultural Heritage Restoration and Conservation projects, the restoration of *Sungnyemun* Gate entailed the highest expenditure in every sense: expenses, time, and expertise. And it will be a touchstone for the future generations in terms of practices of adapted traditional technologies and disaster preparedness.

This paper deals with the issues of restoration and design intervention of the historic gate as an opportunity to promote conservation of heritage and national unity, with a focus on

the case study of *Sungnyemun* Gate in Seoul, Republic of Korea.

The three main focus areas of this paper are:

- 1) review of history of *Sungnyemun* Gate and its various functions;
- 2) the implementation of state-of-the-art technologies for the restoration and conservation of cultural Heritage; as well as new additions of its disaster prevention facilities;
- 3) reassess the symbolic meaning of restoration work as a tool for communication with the public.

This paper suggests a further consideration on continuity between old and new, and identity of the cultural heritage in the rapid changing city of Seoul as resources for the Sustainable Cultural Landscape.

Key words

restoration of historic gate, state-of-the-art technology, continuity and identity, sustainable cultural landscape

Introduction

Sungnyemun Gate – National Treasure No. 1 – was finally reopened after a long and highly anticipated restoration process after the unspeakably heinous arson attack of February 2008. The May 4, 2013 ceremony to mark the restoration rendered public reconciliation and brought the national grief to an end. After the ritual of expelling the past's misfortunes, President Park announced the completion of the restoration to the heavens. She and the participants opened the newly restored gate marking the new era. Through the open gate, a procession took place; over 500 participants accompanied the president to *Sungnyemun* Plaza along with a *Joseon* Dynasty palanquin laden with a “box” containing messages of hope written by the citizens of Korea. Fantastic shamanist dances were performed and the beloved *Airang* was sung by the crowd. *Airang* was a song registered on the UNESCO Intangible Cultural Heritage of Humanity list on December 2012.

Also present at the completion ceremony were those who participated in the actual restoration, alongside volunteers, donors, event officials, and many citizens, including multicultural families, North Korean defectors and their families, and children and teens from disadvantaged families.

The international press took great interest in the restoration effort, too, with about 20 major news services including AP, Reuters, AFP, Xinhua and the Mainichi Shimbun running big stories on the restoration. The international press highlighted the significance of the restoration, citing President Park's speech, in which she stressed “the pride of the people” and “opening

the door to new hope and a new age”. They noted not only that the gate was restored using traditional materials and techniques, but also that the restoration fortified disaster prevention systems.

1) Review of history of *Sungnyemun* Gate and its various functions

History of *Sungnyemun* Gate

Hanyang Fortress, the city wall that surrounded the royal capital of Seoul throughout the *Joseon* Dynasty (1392–1910), was 18.7 km long and integrated into the city's topography. Entry gates were built at major sections of the wall to the east, west, south, and north. Geographically speaking, *Sungnyemun* was not exactly due south, but it was nonetheless the gate that symbolized the southerly direction.

Since *Sungnyemun* was the southern entrance to the royal capital, it is sometimes called *Namdaemun* (*Nam* meaning south), or the “Great South Gate”. Judging from historical records, the term “*Namdaemun*” came into common usage in the late 14th century. In 1933, the Japanese occupation authority designated the gate a national treasure under the name *Namdaemun* rather than *Sungnyemun*.

Sungnyemun was built with an arch entrance in the center of the stonemasonry base, and above that sat a multistory pavilion. The wooden pavilion is five *kan* wide and two *kan* deep (a *kan* is the distance between two columns)¹ and covered by a hipped roof.

The pillar arrangement makes it so that the lower and upper floors of the pavilion are essentially one structure. Prior to the 2008 fire, it was the oldest wooden structure in the city of Seoul.

The name of the gate came from the

word *ye* (Chinese: *li*), meaning etiquette, one of the five virtues of neo-Confucianism² – the political, academic, and ethical basis of the *Joseon* Dynasty. *Ye* corresponds to the south, and according to the Five Elements³ that form the basis of Korean philosophy, it also corresponds to fire. The *Joseon* Dynasty promoted a healthy society through good manners, or *ye*, in accordance with neo-Confucianism.

The signboard of the gate is written vertically, unlike the signboards of other gates. According to Pung-Su (Chinese: *Feng Shui*) theory, Mt. *Gwanaksan* physically resembles fire, and *Sungnyemun* – if written vertically – could protect the gate and the royal capital from the mountain's fire energy by “fighting fire with fire”. Another explanation for vertical writing can be tracked down in the *Analects of Confucius* a person in an upright position (as appose to a sitting person) shows good attitude or manner (*ye*).

Various Functions of *Sungnyemun* Gate

Sungnyemun has played many functions throughout history. According to records, it controlled traffic in and out of the capital. A bell would toll to alert all to the opening and closing of the gates. According to the *Annals of the Joseon Dynasty*, the bell of *Heungcheonsa* Temple was moved to the gate in 1425 (the seventh year of King Sejong). The bell was usually struck 28 times at around 10pm to mark the closing of the gate. At 4am, it was rung 33 times to announce the opening of the gates. *Sungnyemun* was also used as a place where people prayed either for the end of the monsoon rains or, in the case of drought, for the coming of rains.

It was also used as a place to announce major government policies. Criminals were executed here, too, with the king personally adjudicating. It was also a bastion that protected Seoul in times of war. Since its first completion in 1398, *Sungnyemun* was restored in the middle of the 15th century, and in 1860 its pavilion was restored. Its role as Seoul's main gate came to an end in 1907, when parts of its surrounding wall were demolished to allow trams and cars to pass. In 1952, it underwent restores to fix damage from the Korean War, and in 1961–1963, it underwent a full-scale disassembly and restoration. During the restoration, it was named National Treasure No. 1. On February 10, 2008, not even two years after the gate was opened to the general public, it fell victim to a heinous arson attack – 90% of the top floor of the pavilion and 10% of the lower floor were destroyed. Despite the damage, experts felt that the gate should maintain its No. 1 status since the masonry was fine, 90% of the first floor intact, and the repairs would require just fixing the damage, not rebuilding something that had been completely lost. The ridge beam raising ceremony was held on March 8, 2012, and the restoration was completed on April 30, 2013 – about five months behind schedule. The gate was finally unveiled to the general public on May 4, 2013.

2) The implementation of state-of-the-art technologies for the restoration and conservation of Cultural Heritage; as well as new additions of its disaster prevention facilities

Advanced Cultural Heritage Protection and Restoration Technology

The restoration of the gate was a

major national project. It took five years, two months, and 20 days: this included four months of assessing the damage, a year and seven months of preparation, and about three years of construction. The restoration cost about KRW 27.7 billion (about 20 million Euro) and demanded the participation of about 35,000 people, including 3,968 carpenters and 284 to make the roof tiles. Some 26 tons of wood were used, as well as 23,369 roof tiles, 1,332 kg of natural colorings for the paint, and a great deal of granite.

Assessing the Disaster

Radio-frequency identification (RFID) system was employed to categorize the major damaged section. The system affixes an RFID tag to damaged sections; the tag included the name of the part, how badly it was burned, and its location. A handheld reader was used to access the tag information. After emergency preservation and stabilization measures were taken, the damaged parts were taken to a storage facility on the grounds of *Gyeongbokgung* Palace and work on the basic plan for restoration began.

Restoration Preparation

Primary and secondary excavations were undertaken. The excavations revealed the spots of late-*Joseon* Dynasty stone roads to the front and to the rear of *Sungnyemun*, the location of buildings from several eras, and the foundation of the fortress walls that flanked the gate to the east and west.

Much effort went into finding the wood for the reconstruction. Trees from the thick forests of tomb, that of an ancestor of the founder of the *Joseon* Dynasty were felled for the task. Trees in this forest are re-

served only for restoration of buildings of importance. They were also used in the 19th century reconstruction of *Gyeongbokgung* Palace.

The pines were flown by helicopter to Seoul, where they were stored at *Gyeongbokgung* Palace.

Preparatory construction was undertaken, and research and preservation measures were taken on the damaged sections of the gate.

Plans to restore the gate and rebuild the fortress wall were completed, then historical research and studies on ironworking, painting, and disaster prevention were carried out. All the preparations were video recorded.

Restoration Construction

Firstly, the remaining pavilion was disassembled and minute research conducted.

Meanwhile, on the southeast part of the restoration site, a traditional forge was set up so experiments could be made with the traditional metalworking process. Masons laid the granite mined from the mountains using traditional tools to repair the gate's stone foundation and rebuild the flanking walls. Major carpenters used traditional tools to process the wood for restoring the wooden pavilion. Roof tiles crafted by traditional craftsmen and fired in a traditional kiln were put in place using traditional tools. Traditional paints and traditional glues were used, and parts were given a protective coating of tung oil to ward off moisture. Fire and disaster prevention systems were installed and the surrounding area was prepared.

Mass Participation of Intangible Cultural Heritage (Human National Treasures)

The writing on the signboard, which was quickly rescued from the



Disassembling the salvaged parts, 2009 (photo: Shin, Eung-Su).



Both the salvaged (connection beam) and new (column) wood were used (photo: Shin, Eung-Su).

this opportunity to pour interest and love into our cultural heritage with a sense of ownership”.

Shin insisted on using as much of the salvaged wood as possible; for the remainder, he found locally produced pine over 100 years of age, fashioning it by hand using traditional methods.

He considers strong red pine the best material; for the main pillars of the superstructure, he used pine over 300 years old.

Where it would not present any safety problems, he left a piece of wood scorched from the fire as a reminder. On the pillars on the upper floor, he used both the salvaged and new wood.

Shin had also participated in the 1962 repair of the gate.

Having learned under some of the greatest masters of the age, he was able to teach the new generation of major carpenters.

Mason Lee Ui-sang said it was rewarding to contribute to the restoration, especially using traditional methods.

“I was at a loss when they first said they’d restore *Sungnyemun* with traditional methods”, he said, “because the traditional tools used by masons all disappeared in the mid-1970s. I had no choice but to travel the country to purchase old tools to do the work”.

He said he felt better about the restoration of the gate than he’d felt about anything else he’s done for the 55 years as a mason.

Fellow mason Lee Jae-sun noted that because they used stone mined from the ground rather than exposed stone, it would last longer.

He also appreciated the chance to learn the wisdom and the skills of the craftsmen of old.

Use of 3D Laser Scan Technology

During the entire restoration

gate at the time of the arson attack, was restored using rubbings stored at *Jideoksa*, a shrine where the memorial tablets of King Taejong’s eldest son *Yi Je* and his wife are kept.

The traditional manner of crafting palace signboards was recreated to restore the gate’s signboard – a pine board was covered in black lacquer, and the letters engraved in relief and painted with white rice powder.

Of particular note is that masters of Korea’s Intangible Cultural Heritage were mobilized en masse for

the restoration. Masters such as major carpenter Shin Eung-su, mason Lee Ui-sang and Lee Jae-sun, painter Hong Chang-won, tile craftsman Han Hyeongjun, roofer Lee Geun-bok, blacksmith Sin Inyeong, and major carpenter Mun Gi-hyeon and Sin Jae-sun, as well as their apprentices, put forth all their effort during the restoration. Master major carpenter Shin Eung-su, who was in charge of restoring the gate’s wooden superstructure, said, “I gave everything during the restoration of *Sungnyemun* Gate. It would be good if the public took

process, the Cultural Heritage Administration operated an advisory team of experts and oversaw everything directly. It maintained several basic principles:

- that salvaged material be used as much as possible;
- that the gate section be restored to how it appeared prior to the fire;
- and that some part of the city walls, which had been destroyed during the Japanese occupation, be rebuilt as much as possible.

Advanced 3D laser scan technology was employed during the restoration; in fact, since there was 3D scan dating from 2002, it could be referenced along with the manual blueprints.

The 1,916 days of the restoration were video recorded and turned into an archive to be stored as national records. This is a modern take on the documentary drawings of the *Joseon* Dynasty, during which all major events overseen by the royal court were drawn, recorded, and archived.

3) Reassess the symbolic meaning of restoration work as a tool for communication with the public

Symbolic Meaning: Communication with the Public

The registration number of a National Treasure reflects its order of designation. In other words, the first National Treasure ever designated was *Sungnyemun* Gate. That the gate is National Treasure No. 1, it, also reflects the public's love for the historic gate, a icon of Seoul. It's the love that is much more significant than the expert descriptions of the architectural minutiae of the gate.

Accordingly, the restoration of *Sungnyemun* signifies communication with the public and, more than the restoration of a piece of archi-



Reassembling the wooden pavilion-lower floor (photo: Shin, Eung-Su).



The signboard of the gate, after restoration.

tectural heritage, an opportunity to restore pride in Korea's cultural heritage. No wonder why over 20,000 people visited the gate within a day of its opening to the public. To meet the public's enthusiasm, the gate is open to the public 9am to 6pm, Tuesday to Sunday; on Saturday and Sunday, the wood pavilion is open for viewing three times a day for the first 20 visitors.

Restoring the Gate to its Original Condition

The restored gate is not exactly as it was prior to the fire – the fortress walls, demolished during the Japanese occupation, were rebuilt,

and the width of the steps and height of the ground were changed. Some 16 m of wall were added to the west of the gate and 53 m of wall to the southeast of the gate, the eastern stairs were lengthened from 2.9 m to 5 m, and the ground was lowered some 30–50 cm to where it had used to be in the late *Joseon* Dynasty.

Other changes were made to return the gate to its pre-1960s condition, including lengthening the roof line by 1.1 m and changing the floor on the first level of the pavilion from a checkered floor to one made of long planks. The numbers of *japsang* statues on the roof were reduced

from eight to seven. *Japsang* are statues of animals and people placed on the roof of a palace building or gate to ward off bad spirits. Each roof tile was made and fired by hand, not factory produced. Efforts were made to restore the painting on the ceiling of the arch entrance to the way it had been in the early *Joseon* Dynasty.

The most important new additions to the gate post-restoration are its disaster prevention facilities. To prevent disasters, intrusion detection sensors, fire alerts, and a direct hotline to the fire department were added. To deal with fires, an internal sprinkler system has been installed, and fire hydrants and hoses have been added outside the gate. Heat and flame sensors and 18 CCTV cameras have also been installed to allow respondents to tackle disasters early. Fire-resistant material has been added to the roof construction so that it can resist temperatures of over 1,000 degrees Celsius for more than 10 minutes. Lightning rods and conductors have also been installed at critical junctures, and a disaster prevention office was built.

Lighting facilities have also been strengthened. About 90 landscape lights have been added around the gate and its surrounding wall, while 75 LED lights brighten the wooden pavilion, archway and upper parts of the wall. With the Cultural Heritage Administration taking charge of the gate, guards are now posted full-time.

Conclusion

Sungnyemun Gate restoration work will be a touchstone in terms of disaster preparedness, challenge of the materials and techniques applied, and many others in the recovery of Architectural Heritage, not only because of the unprece-

dent amount of time and money spent but also the expertise performed was unparalleled in the entire history of Architectural Heritage Restoration in Korea.

However, what's lacking throughout the whole process of the restoration was consideration of a bigger picture that includes an overall environment of the capital city that could be great resources for the Sustainable Cultural Landscape.

Above all, it should not have overlooked the extensive review process such as the review of the impact on the periphery zone from the Cultural Property, *Sungnyemun* Gate, additional design of fortress wall, urban redevelopment plan, district planning and traffic nuisances. For example, when a certain relationship between the height and distance from the cultural properties regulated which is performed during the whole restoration process, if the Cultural Properties Protection Act was reviewed in the category of city's cultural landscape with a sense of the actual height of the building, Cultural Heritage Impact Assessment for the nearby high-rise buildings has been applied totally differently. After the completion of the restoration work, one notes that a building in the back of the gate stands as if growing out of the rooftop of the gate, and that the advertisement panels with sparkling lights in the vicinity creates a great distraction. This reveals the mistakes of not involving architects, but only skilled builders.

The boundaries between the succession of the heritage tradition and intervention of the new design are not clearly defined. The distinction between the repair and the restoration to show authenticity is blurred. It would help a lot if it could adopt mechanism that distinguishes the original part and re-

paired part in the masonry restoration techniques.

The intention of the mosaic-look stone wall seemed to show the remaining original part. The look might improve as time passes, but it will be very ambiguous when needed restoration work in the future.

Even from an aesthetic point of view, it would have been desirable to display it clearly, which is which: keep the original stones in the original part and mark the newly added mason fortress wall. It would have been much nicer if approached to the restoration work with a little concept of the architecture, e.g. in the connection of the existing walls and the repairing part and in the design intervention when the fortress wall is extended to the southeast, it would have been the better result, if it treated as lowering the fortress wall on the raised terrain, then optical illusion could be corrected and restored wooden structure could be more visible. It is obvious that the recovery of the topography of the *Joseon* Dynasty is not possible, then we should have kept the future project in mind and taken the current situation into account.

It is indeed a good idea to show a cross-section of the fortress wall for the educational purpose, but it would have been better if it had restored the length to keep the balance with the opposite side wall. It would enable the traffic flows while connecting to a small wall lined with perforated walls.

It might lose entire balance because of the obsession of "maintaining the original shape" in accordance with the current laws of the Cultural Property Protection Act and because of the lack of understanding what is the Major in the restoration work – it is *Sungnyemun* Gate itself, not the walls attached, nor the changed

terrain. Even within the criteria of time, it had been taken a modern period in some part, early *Joseon* in other part, and late *Joseon* in another part. It would have been better in the same contemporary of any kind, either early or late *Joseon* to keep the continuity of the cultural landscape. In the current situation of historic urban environment, it had to be carefully decided that the restoration of the Dancheong painting of early *Joseon* on the wooden restoration of the late *Joseon* Period. Nevertheless, we all would appreciate all the efforts and people who are involved in the whole process of restoration work of *Sungnyemun* Gate.

Footnotes

¹ The measurement unit *Kan*: The Term "*kan*" is generally used to name the bay of the two columns. *Sungnyemun* can be describes as 5-*kan* in the connecting beam direction (*Do-ri kan*) and 2-*kan* in the tie beam direction (*Bo kan*).

² Benevolence (*in* 仁 *rén*), righteousness (*eui* 义 *yì*), propriety (*ye* 礼 *lǐ*), wisdom (*ji* 智 *zhì*) and fidelity (*shin* 信 *xìn*) are the Five Constant Virtues (*o sang* 五常 *wǔ cháng*) which are the most important ones in traditional virtues of Confucianism.

³ The "Five elements / Five Phases" are Wood (*mok* 木 *mù*), Fire (*hwa* 火 *huǒ*), Earth (*toh* 土 *tǔ*), Metal (*geum* 金 *jīn*), and Water (*su* 水 *shuǐ*). This order of presentation is known as the "mutual generation" (*sangsaeng* 相生 *xiangsheng*) sequence.

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The *Sungnyemun* Gate.



The *Sungnyemun* Gate.



The *Sungnyemun* Gate.

The Interaction of Timber and Brick Masonry in the Kathmandu Valley*

* Reprinted from "APT Bulletin", ART XXVII-1/2-1996, pp. 74-81.

David Yeomans

A historic structure in Nepal shows how lack of knowledge about materials and workmanship can be both a warning about methods of rebuilding and an opportunity for discovery.

Introduction

Domestic and religious buildings of the Kathmandu valley in Nepal have attracted interest from writers, and the cultural and historic value of the major palaces and religious shrines was recognized on the World Heritage list in 1979. The royal buildings have been described and illustrated in considerable detail by publications of the Nipon Institute of Technology,¹ while Gutschow et al. have illustrated the details of traditional construction.² Unfortunately, the descriptions of individual buildings do not show the details or variety of work-

manship – either the methods and standards of building adopted by the original builders or by those who have repaired or rebuilt. The latter is significant because a considerable proportion of the buildings in the valley were either completely or partially rebuilt following the 1934 earthquake. Our lack of knowledge means that it is difficult to make detailed recommendations for conservation and repair. Some important historic buildings in the monument zone have already collapsed, and others are exhibiting signs of distress. Measures to conserve these buildings require some knowledge of the processes of deterioration and the level of earthquake risk. There are several conservation projects underway, and the author is currently engaged on one involving buildings in Patan Durbar Square, the royal palace

of the capital of one of the three earlier kingdoms in the valley. This work, funded by the Japanese Heritage Trust, has begun with Sundari Chowk, the most southerly of the group of buildings that form a series of enclosed courtyards on the east side of the square (Fig. 1). Work in 1994-95 was principally concerned with a detailed survey of the structure and an assessment of its condition so that a repair schedule could be drawn up. The construction of these buildings is typical of those in the region, and knowledge gained here may be used in the repair of other buildings in the valley.

General Form of Construction

The traditional form of building in the valley is of brick masonry, with walls up to 30-inches thick. The walls are formed of a core of low-fired brick, sometimes of sun-dried brick, between veneers of better quality fired brick, all of which are set in clay mortar. The veneer bricks on the external walls are made with a slight taper to reduce the thickness of the face joints while still allowing a sufficient mortar thickness between courses. Brick sizes vary³ (Fig. 2). Veneers on the inside walls are of better quality brick than the core but lack the refinement of the taper and show thicker mortar joints on the face. The majority of the bricks are stretchers, but there is a small proportion of headers (in this case the term header does not mean an ordinary brick turned end-on to the face of the wall but refers to special bricks, shorter along the course than normal but deeper, to provide some keying to the core masonry). The proportion of headers can be as little as 10% so that this keying may not be very effective. Whatever the original proportion of headers, they were insufficient to prevent some distress. However, the frequency of this behavior is still not known. Although work has been carried out on the monuments in the valley over a period of time by a number of architects, no comprehensive record has been kept of the properties of the materials used in the walls nor of the standards of workmanship. Door and window openings within the masonry walls have elaborate, decorative frames built into the external veneer. These frames are the principal features of the elevations, which are

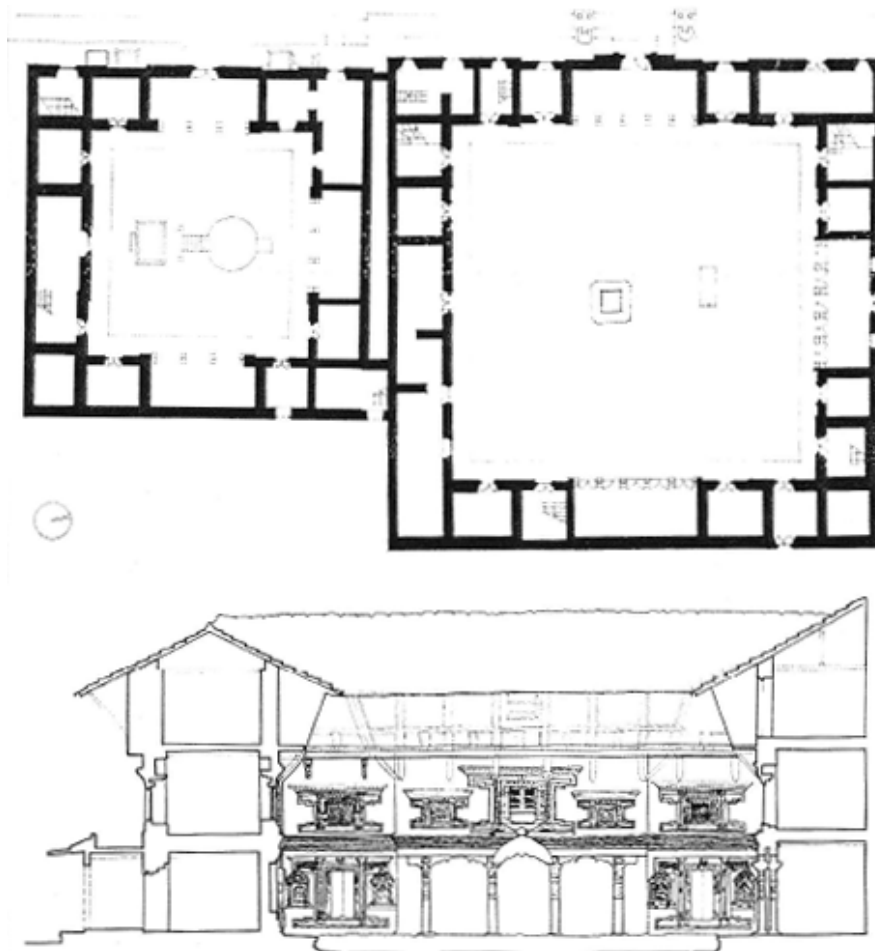


Fig. 1. Plan and section of Sundari Chowk and Mul Chowk.

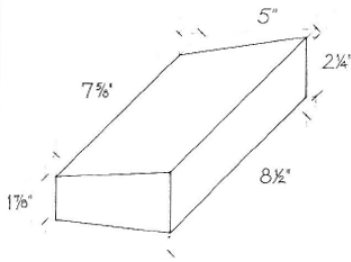


Fig. 2. Dimensions of veneer brick from Sundari Chowk showing taper.

treated, not as a pattern of openings within a wall, but as an infill of masonry around highly carved timber elements. The frames have long, projecting decorative sills and lintels, and in some buildings there are large panels of carved timber between the underside of the lintel and the side posts of the frame. In the courtyard of Sundari Chowk are niches containing carved figures set beside the door frames and under the projecting horns of the timber lintels (Fig. 3). The sills and lintels also have a complex construction. Plain pieces of timber, into which the uprights are joined, are framed by carved pieces, mitred at the corners, but lapping over the structural element (Fig. 4). These are not architraves, which cover the joint between the timber and the masonry, because the brick veneer butts against this frame. Although Gutschorv et al. show the assembly of a window frame,⁴ variations can be found. For example, the door frames in Sundari Chowk have sills formed of three pieces, while in the adjacent Mul Chowk they are a single piece of timber. Simpler, undecorated frames are built into the inside face, while within the thickness of the wall there is a series of simple lintels supporting the core masonry, stepping upward to form a higher opening inside. Commonly, there are voids above these lintels, although the depth of such voids and the profiles of these openings vary (Fig. 5). The external and internal frames are connected by timbers running through the wall, while the sides of the openings are of exposed or plastered brickwork. The floors comprise closely spaced joists approximately 6-inches by 4-inches deep spaced at about 10-inch centers. There is boarding above these and then an overlay of brick and clay to form the floor surface. This overlay may be of considerable depth, as much as 6 inches in some places, and in some rooms the wearing surface is of square clay tiles. The joists are built into the full thickness of the wall and rest on plates set into the veneers at both faces (Fig. 6). Because the size of the joists is lim-

ited and the overlaid floor so heavy, the floor spans are naturally limited. In Patan the width of the rooms is a little less than 10 feet, but wider buildings may be formed with a row of posts and beams down the center. The top floor joists of Sundari Chowk cantilever out beyond the walls to form the floor of an external passage set below the wide overhanging eaves. It is not only the building-in of the floors that affects the behavior of the walls. The timber is such an integral part of the construction that either its decay or the effects of insect attack presents fundamental problems for the whole building.

Conservation of the timber presents special problems, noted by Theophile and Ranjitkar,⁵ arising from the failure of the roofs, which have a fairly simple structure with a king post supporting a ridge beam. Cantilevered rafters form wide overhangs, supported at the eaves by purlins struttled from the top floor. Boarding (originally bamboo) above the rafters carries a clay base into which the traditional pantiles were set. The roof timbers decay if the tile covering is not maintained and water penetrates into the buildings. Decay may also occur in beams supporting masonry and this is a particularly severe problem in buildings of pagoda form, in which the enclosed area diminishes at upper levels by carrying the brickwork on large timbers. Buildings commonly have arcaded openings on the ground floor called dalans (Fig. 1), with the walls of the upper floors carried on heavy beams and posts. In Sundari Chowk there are dalans on three sides of the courtyard, each with three openings. Because of the wall thickness, two beams are needed to carry the load of masonry, and so they are supported on pairs of posts. The outer beams are of the local hardwood, sal (*Shorea robusta*), while the inner beam, which is not so visible, is of pine. The condition of these timbers, particularly the pine, is a matter of considerable concern because decay or insect attack in dalan beams has already led to the collapse of some buildings. There will be further losses unless remedial action is taken soon. The construction of the dalans in the palaces differs from normal construction within the valley. Posts and beams are much more substantial than in many of the buildings, and the posts stand directly on the stone paving. Elsewhere it is common for posts to stand on a timber plate, whose decay has led to failure of other buildings in the valley. Decay also occurs in timbers within the face of the wall at ground level, either the timbers of the window and door frames or of the exposed ends of the

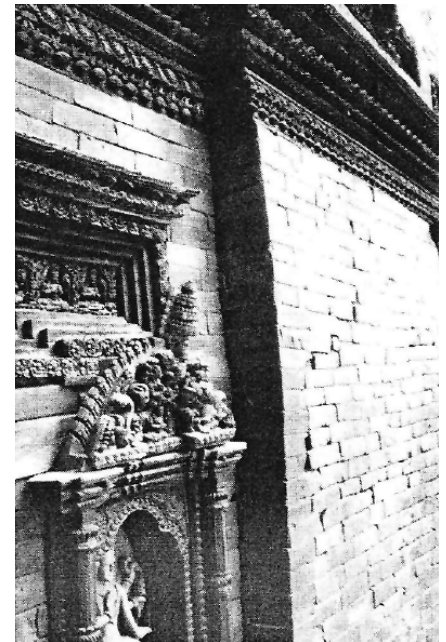


Fig. 3. Part of the wall on the south side of Sundari Chowk. The return at the end of the plain panel of brickwork shows the bulge in this panel. The disruption to the coursing in this panel is also clear. A small niche with the decorative door lintel above it can be seen at the lower left.

floor joists. This may be caused by water splash from the stone paving during the monsoon or from rising damp within the walls, possibly both. Unfortunately it has not been possible to carry out longterm monitoring to determine either the cause or the extent of this dampness, but efflorescence on the brickwork is sufficient indication, that it is a serious condition. It has already caused the loss of components of the timber sills of ground-floor openings. Wood carving is still a flourishing craft within the valley, so that replacement of decorative work, where necessary is not a particular problem. Of more concern is the possible effect of decay on the structure of the wall and the way in which the timbers interact structurally with the masonry.

The Walls of Sundari Chowk

The investigation reported here was concerned principally with the south wall of Sundari Chowk where there was no dalan. It is thus more typical of the rear walls of small buildings or the outer walls of the courtyard buildings. The courtyard buildings of Sundari Chowk suffered severe damage during the earthquake of 1934. There is evidence of collapse-and rebuilding of the eastern half of the courtyard where the quality of decorative brick coverings over the timber lintels is poor compared with original moulded brickwork in the remainder of the building. Of particular concern in the

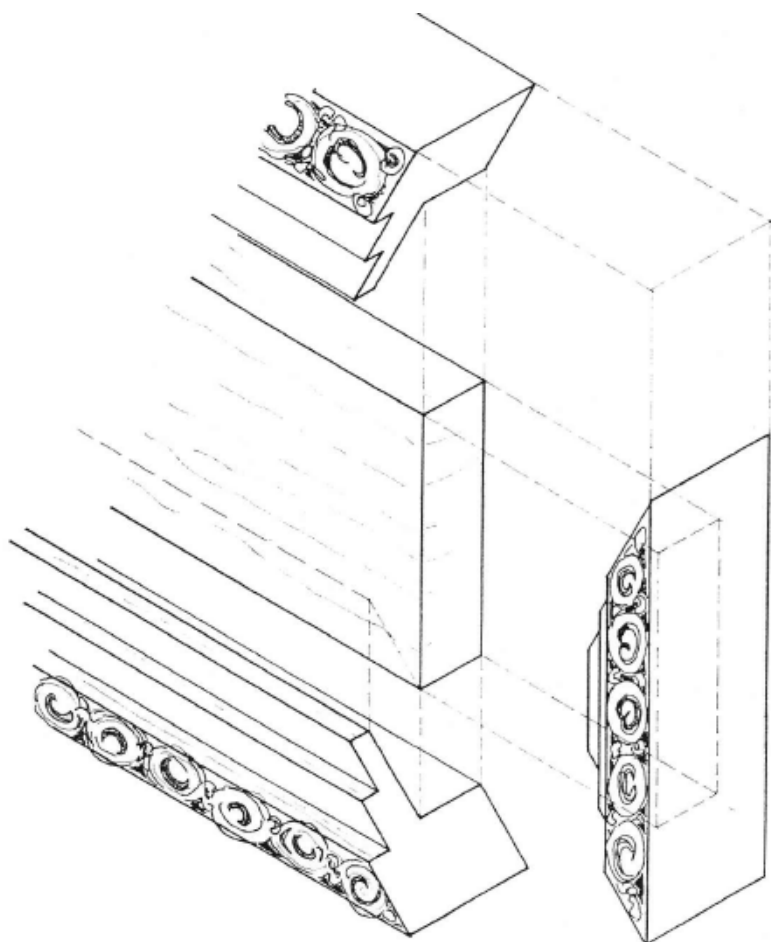


Fig. 4. Sketch of the assembly at the end of a lintel or window sill, in which decorative pieces mitred at the corner frame the structural member.

present investigation was severe bulging of the ground-floor wall on the south side of the courtyard (Fig. 3). The bowed appearance of the wall is the result of movement between the veneer and the core because of poor bonding between them. It is clearly desirable to ensure proper attachment of the veneer to the core. Further movement and possible collapse seem likely. Even a minor earthquake shock may cause collapse of the veneer. In the absence of any traditional technique of repair, it was suggested that metal cramps be used to attach the veneer to the core; while this might restrict further movement, the mechanism causing movement needed to be explained before such a repair could be adopted with confidence. Two possible causes of movement were considered initially. Because the veneer bricks are tapered, any loss of clay mortar from the joints could lead to the kind of bowing observed as the bricks settled against each other. The possible extent of such movement could be determined from the geometry of the bricks. The other possibility was that the veneer is being called upon to carry load. Unless bonded to the core, the veneer under load would act as a thin structural wall

with a slenderness ratio approaching 1:15, depending upon the degree of restraint assumed at the top and bottom. Any tendency toward buckling failure in this thin wall would be exacerbated by the shape of the bricks. This would be a more serious condition because it could not be dealt with by simply attaching the veneer to the core. It would also have implication for repairs to the timber frames built into the veneer. The crushed condition of one of the sills in the north-west corner and the local bulging of brickwork beneath one of the niches (Fig. 7) showed that there was compressive load in some places, although elsewhere brickwork in the veneer was so loose that bricks could easily be removed by hand. The pattern of stresses within the wall was far from simple and required explanation. The most striking evidence for load in the veneers is in the surface appearance of a large panel of masonry in which there are no openings. Here differences in joint width and some dislocation in the bonding have resulted in an arch-like pattern at the top, where there are tight joints between the courses (Fig. 3). Below is an area of loosely jointed brick whose condition



Fig. 5. Rear view of an upper floor window opening. The floor joists and wall plate are visible at the top.

not only indicates that it is unloaded but suggests that it is a repair following a collapse. Other signs of distress are the considerable local bulging underneath one of the niches, bricks that have split across the face, and some spalling of brick faces. The last appears to be associated with compressive forces directly between bricks in adjacent courses. This and other effects are difficult to account for without assuming compression in the veneer. Observation of the timbers confirmed that there was compressive load in some places.

If the veneers are under load, it will have implications for the repair of the decorative timber frames. Many of the timber frames of ground-floor openings are in a poor state. If there is load in veneers and forces are being transmitted to these timbers from the brickwork above, it might be difficult to remove any decayed timber for repair or replacement. The possibility of load being delivered to the veneer by the floor timbers raised questions about the effect of remedial measures to improve the load transmission within the core. While compressive forces in the veneer may be causing bulging in some places, they might equally be serving to hold the bricks together. Any removal of this compressive force might reduce the wall to a stack of loose bricks.

Load Transfer and the Function of the Floor

Floors have the effect of dividing a wall into separate lifts so that it cannot be considered as a single structural entity. At the same time, the construction of the window openings also divides the wall so that it must be treated as separate story-height panels. This has implications for mechanisms of load carrying under both static and earthquake condi-

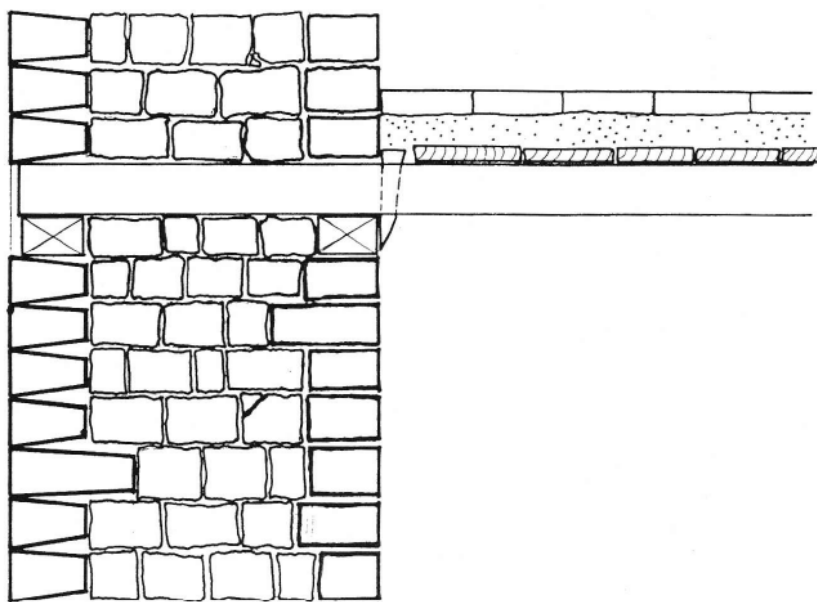


Fig. 6. Sketch section of the junction between the timber floor and the wall.

tions. The conditions at each floor and the mechanism of load transfer must depend upon the behavior of the built-in timber posts. Joists and their supporting plates, built in as the wall was raised, would have been laid upon the masonry and provided the working platform for raising the next lift of the wall. The load of the floor, if then applied, produces a load on the inside wall plate, although this would be small compared with the load from the masonry subsequently built above. If the weight of each successive lift of masonry, and any load that it was called upon to carry, produced a uniform distribution of load on the length of joist embedded in the wall, there would be a uniform distribution of load to the top of the lower section of wall. This assumes complete contact between the joists and the masonry below. However, even if such a condition had been achieved initially, it might not be true of the present state of the wall. Any settlement of the core relative to the veneers within the section of wall below the joists would leave the joist unsupported by masonry. They would be spanning the two wall plates. Such relative settlement of the core seems quite likely given its poorer standard of construction. It will be apparent from Fig. 5 that the effect would be for load from the wall above to be transferred, via the joists, to the plates and so to the veneers. Whether or not this is a possible explanation for apparent compression in the veneers depends upon the ability of the joists and the timber plates to resist the compressive forces that would consequently occur between them. If the forces were sufficient to produce crushing of the timber, then any

settlement of the core beneath the joists would be accompanied by this crushing, and the joists would simply settle with the core. The first task is to calculate this compressive stress.

An estimate of the load arriving at the first floor can be made by calculating the weight of the construction above. Some this load on the joists and plates and the consequent stresses in the timber can be assessed. Regrettably, no measurements have been made of the densities of the materials, which may vary considerably so that there is some uncertainty about the actual value of the stresses within the materials. However, the purpose of the calculation is simply to ascertain whether the suggested mechanism of load transfer into the veneers is possible, because this will affect the method of repair. The estimated value of the stress at the bearing surface between the joists and plates was 8 N/mm^2 (1160 lbs/in^2). Whether this is regarded as a large or small stress depends upon the performance of the timber. The standard text by Chowdhury and Ghosh⁶ gives limited information on the material. More recent studies by Sekhar and Rajput⁷ show that some variation in properties is to be expected depending upon the locality in which the timber has been grown. Values for compressive stress at the elastic limit vary from 100 to 180 kg/cm^2 , the lower of these values translating to about 10 N/mm^2 , providing some reserve before crushing of the timber. Rajput, Gupta, and Singh⁸ have looked at the creep behavior of the material under bending loads and shown that the significance of this depends upon the stress level. Any tendency for creep in compression



Fig. 7. Local bulging of brickwork beneath a niche. The panel of brickwork on the left is the other end of the panel shown in Fig. 3. The decorative timber of the door sill (lower right) has decayed severely, and the small vertical piece has been replaced with brick tiles.

along the grain would have the effect of allowing the joists to settle with the assumed movement of the core, although this would still require load to be transmitted to the plates and so to the brick veneer. The theoretical model for how compressive loads might have developed within the veneer did not require excessively large stresses in the timbers. Therefore, it was considered useful to open up the structure to confirm the suspected behavior. A small section of veneer was removed from the inside face of the wall just above the first floor to provide access to a section of the core of the wall behind. Material was then taken from above and between the joists. Once this had been removed, it was possible to see the top surface of the wall below and to examine the area underneath the joists. This examination was facilitated by using a boreoscope to look at the bottom of the joists on either side of the cleared area. From this it could be seen that there was some settlement of the core of the wall beneath the floor joists. Although it was not possible to obtain any accurate measure of the extent of this settlement, it was sufficient to confirm the mechanism of load transfer within the wall and hence the cause of the distress observed.

Load Transfers in the Veneers

Once the mechanism of load transfer into the veneers was established, the condition of the wall was examined to see what parts were carrying load. While the pattern of loading readily apparent in the clear panels of brickwork,



Fig. 8. Variations in brick joints between a niche and a door sill as a result of different compressive forces. This sill has also had timber replaced with brick tile.

the inclusion of window and door frames complicates the situation. If there is a load in the veneer, it is quite possible that some of this load will also be carried by the timbers of the windows framing the various openings. Any decay in the timbers of these openings under load may then result in a redistribution of this load. Thus, the condition of the structure today may be the result of not only one change but possibly two or more.

In the clear panel the loads are transferred, by the arching action observed, to the stiffer returns in the brickwork. In other areas the distribution of load is affected by the openings. Where there are door frames, the lintels will carry the load to the uprights. These may then act as stiff compression members within the structure and transmit the load directly to the sills, thus relieving the adjacent brickwork of load. The problem with this mechanism of load transmission is that in many instances the sills have decayed where they rest against the brickwork at the bottom. This has allowed the posts to drop and the lintels to deflect. The effect of this must be to transfer load either to the brickwork beside the uprights or to the ends of the lintels. In fact, the brickwork beside the uprights is divided into sections by the lintels of niches on either side. These are jointed into the door frame uprights and would therefore have dropped with them. What actually seems to have happened is that load has been transferred to the ends of the lintels and down the stiffer brick returns, which accounts for the generally loose brickwork above the sills. Fig. 8 shows the kind of

variation that can occur in the joints, indicative of variations in compressive forces in the veneers. It also shows the cracking and spalling of bricks as a result of movements that result from these varying forces.

In the corners between the north wall and the east and west walls there are a number of fractured bricks and considerable spalling of the surface, indicating that load is being carried here. Under these areas of distressed brickwork there are niches whose lintels and sills must receive this loading, and it seems difficult to imagine that the brickwork would fail before pieces of timber. It is true that one of these pieces is suffering from obvious compression failure, but investigation showed that this piece had decayed so that the load is not being carried by a reduced section. Elsewhere, where it was possible to measure the depth of the lintels and sill timbers, it was found that there was a difference of between 2 and 4 mm between the two ends. The smaller dimension was always at the end taken to be in compression, confirming that the load was being carried in the manner assumed. However, it is still necessary to explain why the timbers are not showing more obvious signs of distress when the brickwork is. The answer must lie in the shape of the bricks. The effect of the taper and the use of clay mortar will be to bring load first to the face of the brick where there will be very high contact stress. This might be sufficiently high to cause visible signs of failure at loads too low to produce crushing stresses within the original sections of timber. Time and decay may well change this balance.

An effect of uneven loads delivered to the ground level was seen in the deformation of the sills at the two ends of the north wall. Settlement of the ends of the panels of brickwork into which these are built has caused them to bow upwards so that the center is now 2 cm and 2.5 cm above their ends. The timbers of the decorative pieces at the bottom of the sills had sufficient slope of grain that they were unable to accommodate the accompanying strain and have fractured. At the west end this combined with decay and resulted in the loss of half of the fractured piece. Of course this is not necessarily attributable to the transmission of loads down strong points in the structure. The presence of an opening must relieve the wall immediately below it of load and, although the foundations in this construction are deep enough to ensure even loading to the ground, the differential movement observed here may be the result of consolidation in the clay mortar.

Composite Behavior

It will be clear from the description that the behavior of this structure depends upon the interaction of walls and floors; the construction is responsible for the inconvenient distributions of loads within the walls. Loaded as they are, there must be some concern for the ability of veneers to withstand earthquake shock. On the other hand, that floors are built into the wall provides the potential for restraint against earthquake forces. They may also ensure continuity between the separate panels of brickwork between openings. The present task is to consolidate the walls and ensure proper connection between them and the floors with the least intrusion. There has been regrettably little work on the earthquake performance of masonry structures of this kind. Many of the observations of earthquake failure and the few experiments on masonry performance have been on thin brick masonry walls constructed with brittle mortars.⁹ The most significant patterns of failure in such walls have been out of plane rotation of complete wall panels, where the direction of ground movement has been perpendicular to the wall, and shear failure of panels between window openings, where ground movement direction has been parallel to the wall. Such observations have little relevance to thick walls laid in clay mortar. Some analysis of patterns of failure in this type of construction would be valuable but would have to depend upon such sources as photographs of the damage caused in the 1934 earthquake.¹⁰ Evidence of the behavior of

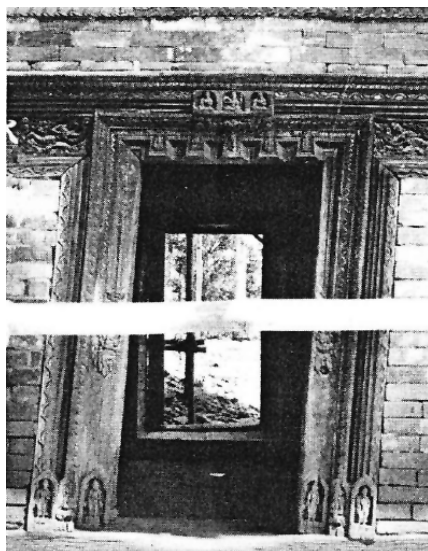


Fig. 9. Racking of a door frame as a result of horizontal shearing between brick courses. Contrast this with the undisturbed frame behind. The horizontal feature is a bamboo scaffoldpole.

similar types of construction may also be relevant,¹¹ and UNESCO¹² has published guidance notes on the performance of masonry walls.

An example of our lack of understanding can be seen in the walls of Mul Chowk, the courtyard immediately adjacent to Sundari Chowk. On the east side of the courtyard, where the upper floor is known to have collapsed and been rebuilt after the 1934 earthquake, the ground floor walls have noticeable in-plane distortions most clearly visible in the racking of door frames (Fig. 9). This could not be the result of any static loading, and one must assume that it was produced during earthquake. The assumption must be that under horizontal ground movement the bricks have slid over each other, moving progressively with each cycle.

Curiously, this pattern of distortion is not repeated in the back wall of the building, about 7 feet behind, and also visible in the photograph. This back wall has far fewer openings, which might account for the difference in behavior.

Conclusions

There has been no intention to discuss the implication for repair of this structure¹³ but rather to indicate our present state of knowledge. The sequence of events followed here, going from general observation through conjecture and structural calculation before a surgical investigation was carried out, has general applicability and may be familiar to other conservators. The process requires some basic knowledge of the particular form of construction, observa-

tion of its present state, and some imagination to suggest possible modes of behavior. The calculations used to examine these possibilities need not be as accurate as those used for design work. They must be within sufficient limits to give the conservator some confidence that the assumed behavior has been correctly identified and to indicate where physical examination of the structure will provide supporting evidence. In this case there was both a lack of data on the properties of the timber being used and of information on the construction of the building, but an accurate diagnosis was still possible. The engineering conservator needs two quite different sources of information, one based on scientific experiment and the other on the observations and measurements made by building archaeologists. While deficiencies in the former may be made good by undertaking further laboratory work, it is more difficult to make good the lack of archaeological data. Of course it may well be supplemented by information from other conservators.

In the type of construction dealt with here, problems of interpretation are created by the interaction of masonry and timber. The behavior of the ground floor walls of Mul Chowk suggest a behavior under dynamic loading that has not been reported elsewhere, but it is not clear what contribution the built-in floor timbers may have made to this. Whether considering static or dynamic loading, the behavior of the walls cannot be understood as masonry alone but must take full account of the composite action with the timber. Detailed observation of the walls on Sundari Chowk show that the resulting complexity is exacerbated by the variable levels of decay in the timber and the degree of loss of clay mortar. There needs to be more observation and recording of movements within the structures of the valley before they are fully understood so that unintrusive repair techniques can be adopted.

David Yeomans is an engineer and historian who writes principally on timber structures. He has taught structures, construction and conservation principally at Liverpool and Manchester Universities and was a founding member, sometime secretary and now honorary member of ISCARSAH and is a member of the ICOMOS Wood Committee. His work as a historic preservation consultant includes assignments for UNESCO in Nepal.

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Notes

¹ *The Royal Buildings in Nepal: A Report on the Old Royal Palaces of the Kingdom of Nepal* (Tokyo: Nipon Institute of Technology, 1981).

² N. Gutschow, B. Kölver and I. Shresthacarya. *Newar Towns and Buildings: An Illustrated Dictionary* (Sankt Augustin: VGH, 1987).

³ The reasons may be variation between different moulds, variations in the properties of the clay body used, and possibly different firing conditions.

⁴ Gutschow, pp. 199-201.

⁵ E. Theophile and R. Ranjitkar, "Timber Conservation Problems of the Nepalese Pagoda Temple", in K. E. Larsen and N. Marstein, *ICOMOS International Wood Committee Eighth International Symposium, Kathmandu, Patan and Bhaktapur, Nepal* (Norway: Tapir Forlag, 1994).

⁶ K. A. Chowdhury and S. S. Ghosh, *Indian Woods*, Vol. 1 (Dehra Dun, India: Forest Research Institute, 1957).

⁷ A. C. Sekhar and S. S. Raiput, "Physical and Mechanical Properties of Sal (*Shorea robusta*) from Fourteen Different Localities in India", *India Forester* 94 (2, 1968): pp. 175-181.

⁸ S. S. Rajput, V. K. Gupta, and K. R. Singh, "Studies on Creep Behavior of Shorea Robusta (Sal) under Constant Loading", *J. Timber Dev. Assoc. (India)* 26 (1, 1981): pp. 30-37.

⁹ M. Bruneau, "State-of-the-Art Report on Seismic Performance of Unreinforced Masonry Buildings", *ASCE Journal of Structural Engineering* 120 (Jan. 1994): pp. 230-251.

¹⁰ The author has been shown one such collection of photographs taken at that time, but these have not been published and are not publicly available.

¹¹ See for example R. Langenbach, "Bricks, Mortar, and Earthquakes: Historic Preservation vs. Earthquake Safety", *APT Bulletin* 21 (3-4, 1989): pp. 30-43.

¹² P. Pichard. *Emergency Measures and Damage Assessment After an Earthquake: Studies and Documents on the Cultural Heritage* (Paris: UNESCO, n.d.).

¹³ The repair schedule submitted for consideration by the donors is the responsibility of my colleague David Michelmore.

Kathmandu Valley World Heritage Site Revisited: Some Reflections on the Scientific Documentation, Conservation and Management of Patan Durbar Square, Nepal*

* Reprinted from R. White and J. Carman (eds.), *World Heritage: Global Challenges, Local Solutions*, British Archaeological Reports, International Series 1698, Oxford: Archaeopress, 2007, pp. 55-61.

Jason Wood

«Patan Durbar Square [...] the most picturesque collection of buildings that has ever been set up in so small a space by the piety and the pride of Oriental man».
Pereval Landon (1928)

Introduction

This paper describes the results of work undertaken by the then Lancaster University Archaeological Unit (LUAU) on behalf of UNESCO at the Kathmandu Valley World Heritage Site, specifically the introduction of a new programme of scientific documentation within the context of the HMG/UNESCO/Japan Trust Fund Project for the conservation and management of Patan Durbar Square in Nepal. The project was established in 1991 and controlled by UNESCO

through the aegis of His Majesty's Government (HMG) Department of Archaeology. The Japanese fund met the budgets for the provision of scientific documentation (archaeological and architectural recording and historical survey), structural analysis, preparation of conservation design proposals and cost estimates, and training of a Nepalese team (including the purchase of capital equipment).

The paper concludes with a retrospective exploration of how the new technologies played an enhanced role in further scientific documentation within the Patan Durbar Square Monument Zone and in the creation of a Development Control Unit for the World Heritage Site. Unfortunately, the lack of continued funding and attraction of better paid work elsewhere conspired seriously to

reduce the capacity of the Nepalese team and today the World Heritage Site is officially recorded on the World Heritage in Danger List.

Kathmandu Valley World Heritage Site

The Kathmandu Valley World Heritage Site, as inscribed on the World Heritage List in 1979, is a single cultural site consisting of seven Monument Zones, of which Patan Durbar Square is one. The other Monument Zones are the Durbar Squares of the cities of Kathmandu and Bhaktapur, the Buddhist temples of Swayambhunath and Baudhanath and their stupas, and the Hindu temples of Pashupatinath and Changu Narayan (see Thapa, this volume).

1979 also saw the launch by UNESCO of an International Campaign for the

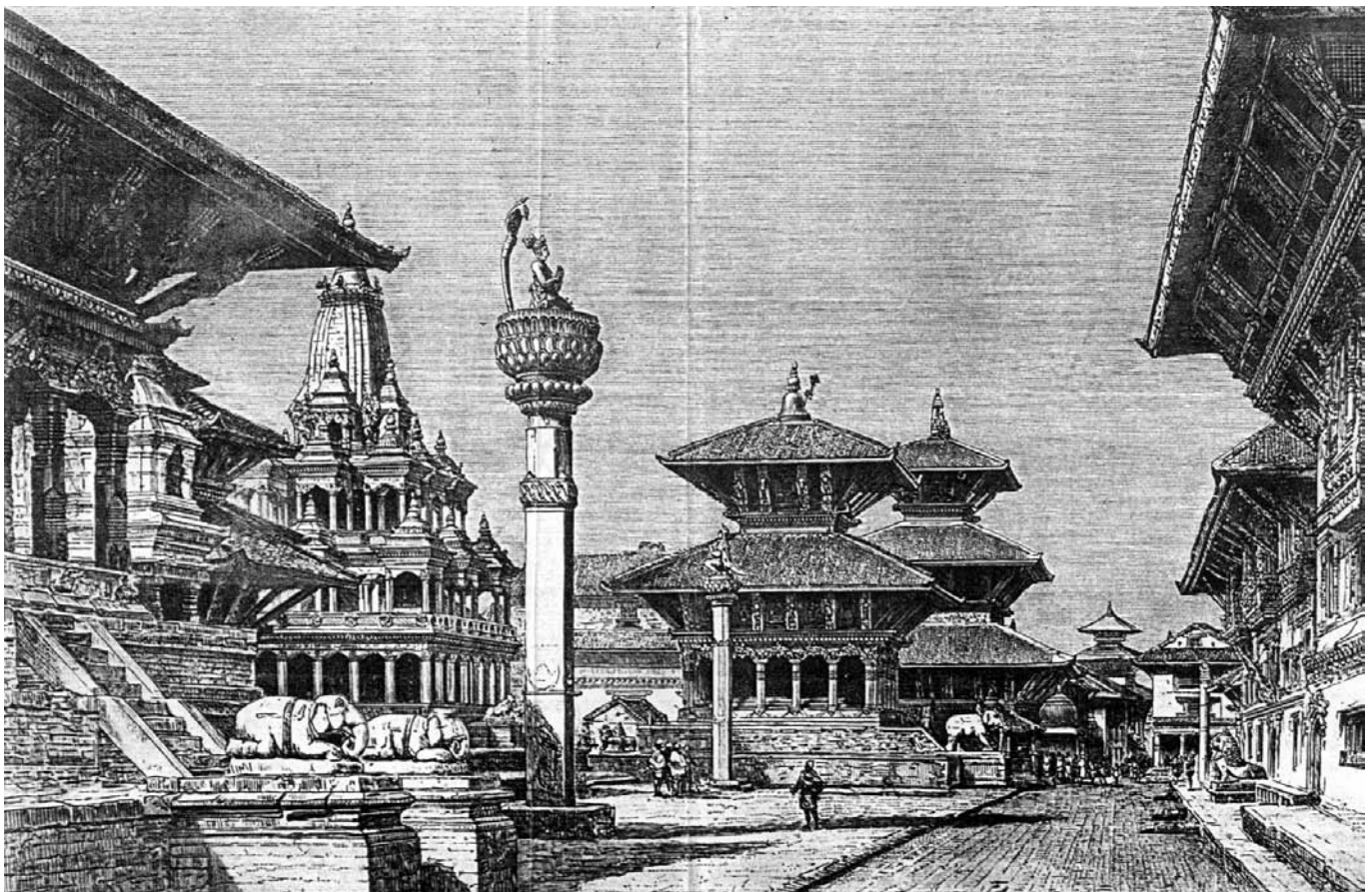


Fig. 1 An etching of Patan Durbar Square, reproduced from *Le Tour du Monde. Voyage au Népal* (Paris 1886) by Gustave Le Bon.

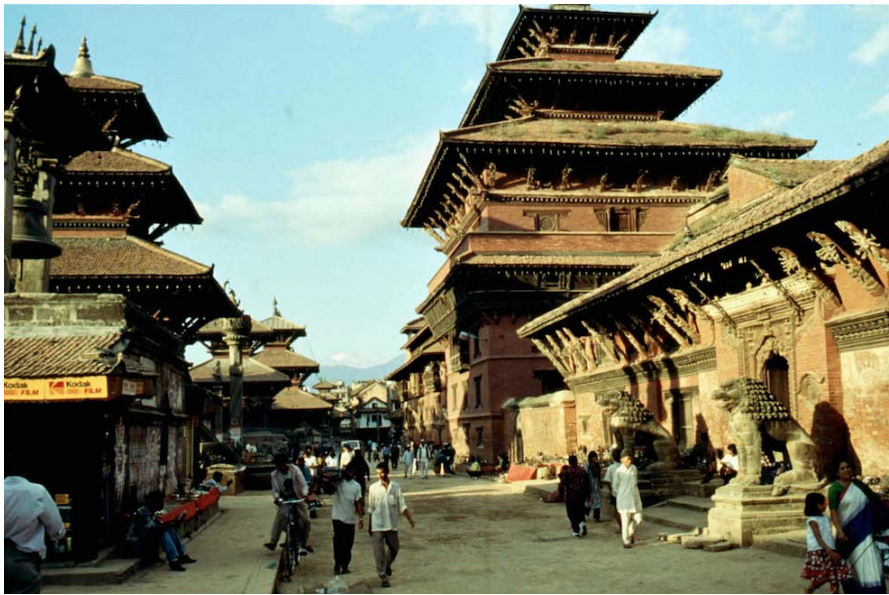


Fig. 2 Part of the monumental façade of Patan Durbar, facing the square, including Mul Chowk (right) and the temple tower of Degu Talle (centre). Photo: Author.

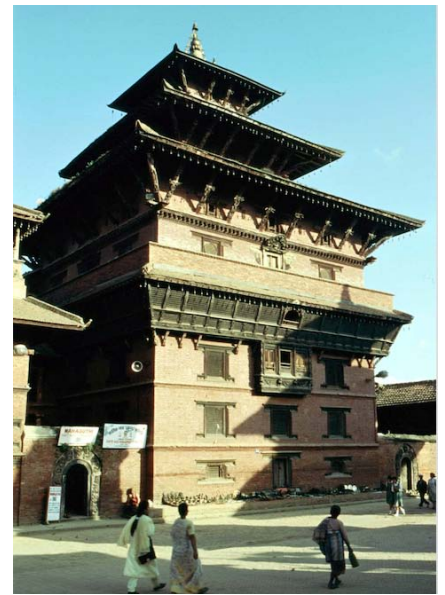


Fig. 3 Degu Talle, the largest of the temple towers. Photo: Author.

Safeguarding of the Kathmandu Valley. This campaign provided a funding and organisational base for a series of projects focused on individual monuments within the World Heritage Site. In this respect, the campaign built on the success of earlier work carried out under the aegis of UNESCO, most notably that of the restoration of the Hanuman Dhoka Palace in Kathmandu and the consolidation of the hilltop at Swayambhunath in the early 1970s. In 1993, the campaign Plan of Action was updated for the additional conservation of selected buildings, particularly in the Monument Zones of Patan Durbar Square and Changu Narayan.

Patan Durbar Square Monument Zone

Patan, or Lalitpur – ‘The Beautiful City’ – as it is often called, lies across the Bagmati River south of Kathmandu. The Patan Durbar Square Monument Zone lies in the centre of the old city and consists of the Durbar (palace) itself, an adjacent temple-filled square at the intersection of the principal roads, and a network of dwellings and isolated monuments in the area around the whole (Fig. 1).

The present palace dates mostly to the 17th century and the reigns of the Malla kings Siddhi Narasingh (AD 1619-61) and his son Shri Nivas (AD 1661-84), and derives its style from the distinctive canon of Newari architecture. Originally, the palace buildings were simply grander versions of the traditional Newari house, but overtime they developed into extensive complexes, integrated architecturally around courtyards (chowks) and commonly attached to

pagoda temple towers with their characteristic multi-tiered roofs.

The main buildings of Patan Durbar are Sundari Chowk, Mul Chowk, Nasal Chowk, and Keshav Narayan Chowk, and the temple towers of Agan Mandir, Taleju Mandir, and Degu Talle. The monumental façade of the palace ensemble, facing the square, is approximately 100m long, comprising the elevations of the three principal courtyards (Sundari Chowk, Mul Chowk and Keshav Narayan Chowk) and the largest temple tower (Degu Talle) (Figs. 2 and 3).

The palace buildings and temples are built using the same materials. Windows, doors and structural elements such as posts, lintels and beams are always constructed in wood, while the walls consist of veneers of bricks with thin clay-mortar joints. Elaborately carved and painted wooden struts support heavy tiled roofs with wide overhangs. Many of the windows with their intricate latticework are more decorative than functional, allowing for considerable elaboration in their forms (Korn 1976, NIT 1981 and 1985, Hutt 1994) (Fig. 4).

Following the establishment of Kathmandu as capital of Nepal in 1770, Patan Durbar lost its function as a royal residence. It continued to house various administrative departments but was not substantially altered by the later Shaha and Rana dynasties. Some buildings however were considerably damaged in the large 1934 earthquake but were mainly rebuilt to replicate the Malla dynasty style and shape. At the time of the project, sections of the palace served as schools, museums and various offices but many parts remained unused.

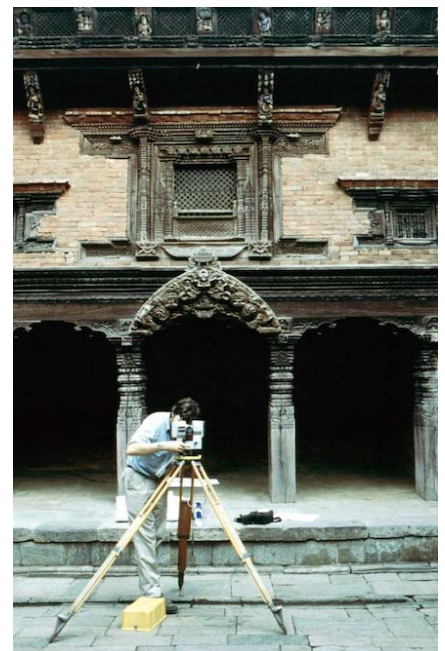


Fig. 4 Part of an elevation within the courtyard of Sundari Chowk showing the decoration typically applied to wooden windows, doors and roof struts. Photo: Author.

Project background

Prior to project, the most recent and major study on Patan Durbar had been that undertaken by the Nippon Institute of Technology in Japan between 1978 and 1980, under the leadership of Dr Michio Fujioka and Dr Katsuhiko Watanabe (NIT 1981 and 1985)¹. The Japan Trust Fund Project, as originally conceived in 1991, envisaged the involvement of one Japanese team and one Nepalese team with international support and leadership to implement the scientific documentation and conserva-

tion design proposals. However, Dr Watanabe was unable to accept UNESCO's invitation to become involved. Instead, in 1992, UNESCO commissioned Dr Hans Bjonness of Trondheim University to draw up preliminary recommendations, guidelines and plans for the scientific documentation (UNESCO/JTFP 1993). In 1993, a joint UNESCO/ICOMOS review mission to Nepal highlighted the extent of the threat to the Kathmandu Valley World Heritage Site, and made specific recommendations for increased awareness of the need for scientific documentation (UNESCO/ICOMOS 1993). In response to this, Dr. Bjonness was appointed in 1994 to mobilise a Nepalese team with responsibility for archaeological and architectural recording and historical survey. Commencing with Sundari Chowk, a team of conservation architects and draughtspersons began recording work, with historical survey being conducted by senior representatives of the Department of Archaeology (HMG/UNESCO/JTFP 1994a, 1994b, 1995a). Later in 1994, at the instigation of UNESCO, an additional need to examine the application of computer-assisted recording techniques was proposed and LUAU was invited to act as consultants.

Project aims and objectives

During 1994 and 1995, LUAU advised on the selection and purchase of survey and computer equipment, performed an evaluation of instrument survey and computer-assisted recording techniques, and actively participated in the local training of the Nepalese team. The results of the evaluation led to revision of the previous project survey methodology and timetable. It was concluded that instrument survey, as opposed to hand-measured survey, would form the basis for the generation of plans and cross-section drawings by the Nepalese team, and that a photogrammetric survey would be implemented to complete the generation of elevation drawings. Both survey techniques were linked to CAD systems to allow for the onward processing of the survey data by digital means. In addition, a seminar was held to broaden the professional skills of the Nepalese decision-makers to ensure the future establishment of effective systems of integrated urban and strategic planning to safeguard the World Heritage Site through development control. LUAU's work was performed under five separate UNESCO contracts. The initial contract was to provide advice on the selection and purchase of survey equipment which UNESCO wished to acquire for the project. The

resulting report outlined the choice of appropriate total station, data logger and peripheral equipment; identified suitable suppliers; described the testing procedure to ensure compatibility, and made recommendations for operating efficiency in Nepal (HMG/UNESCO/JTFP 1994c). LUAU's second contract explored various options for the implementation of instrument survey and computer-assisted recording techniques. Fieldwork to evaluate the most appropriate methodologies took place at Sundari Chowk and Taleju Mandir in late 1994. This was linked to a training workshop for the members of the Nepalese team working on Sundari Chowk and various representatives of the Department of Archaeology. A principal objective was to identify those staff that showed potential as re-trainers. In addition to running the workshop, LUAU took part in a professional seminar entitled 'Innovative Conservation of Cultural Heritage in Nepal' that sought to inform the donor organisations of new developments in conservation practice, while at the same time broadening the professional and technical skills of the decision-makers to ensure that future work met the necessary high standards.

The third contract involved advice on the selection of computer equipment, an additional training workshop, and the drafting of specifications, cost estimates and tender documentation for a proposed photogrammetric survey (HMG/UNESCO/JTFP 1995b and 1995c).

LUAU's fourth contract was to complete the training of those members of the Nepalese team selected to advance the use of computer-assisted recording techniques. During this period the area of fieldwork was extended and new instrument survey was commenced in Mul Chowk and Taleju Mandir, primarily aimed at the production of ground and first floor plans. The greater part of the contract however was concerned with the provision of photogrammetric survey of the remainder of the palace, specifically the external elevations and details of Mul Chowk, Nasal Chowk, Agan Mandir and Degu Talle². The survey was achieved through a specialist subcontractor (Atkins AMC) following a competitive tender process.

The fifth and final contract oversaw the translation and delivery of the photogrammetric data to Nepal and the enhancement and completion of all plan, elevation and cross-section data produced during the training workshop and undertaken by the Nepalese team subsequent to LUAU's departure from Nepal in mid 1995.

Survey methodologies

The initial survey methodology adopted by the Nepalese team mobilised by Dr Bjonness was designed to produce very detailed 1:20 (soon revised to 1:10) drawings of the plans, elevations and cross-sections of the Sundari Chowk courtyard, sunken bath and surrounding buildings, together with constructional and architectural details at 1:5 and 1:1 scale. The parts of the building damaged by the 1934 earthquake and subsequently rebuilt were not to be recorded to the same extent (Fig. 5). Fixed ground control points had earlier been established by a consultant surveyor but there was limited control on the elevations and none at all in the upper parts of the buildings. The methodology for producing the drawings relied on hand measurements offset from a string grid of 1m squares. The initial pencil drawings on plastic film were then inked up. Although very labour intensive, the argument was put forward that it was desirable to employ a large number of local staff and that such staff may not be able to handle or understand more advance methodologies.

Production of the drawings proved to be a slow process. UNESCO was keen to accelerate the recording system as the drawings were urgently needed to serve as the basis for conservation proposals. Following the training workshop, the use of instrument-based and photographic-based survey methodologies and computer-assisted recording techniques was approved by UNESCO. LUAU were encouraged to step up the training with the intention of identifying likely candidates from the existing Nepalese team who could continue using the new technology in the areas of the palace beyond Sundari Chowk. At the same time it was ensured that the remaining work on Sundari Chowk was completed efficiently using new instrument survey to digitally record the upper plans of the building, while new hand survey drawings and earlier drawings not yet inked up were digitised. Guidelines for revised hand survey methodology were issued (UNESCO 1995) and a draft plan of action was agreed (Nepal/UNESCO/JTFP 1995) involving a change in project management, and one in which the Department of Archaeology was able to play an enhanced and central role (Fig. 6).

The use of photogrammetry was considered particularly appropriate to complement the work of the Nepalese team and to considerably speed up the process of recording the complexity of the external elevations, high level plans and cross-sections. Indeed, it would have been difficult to survey the tall

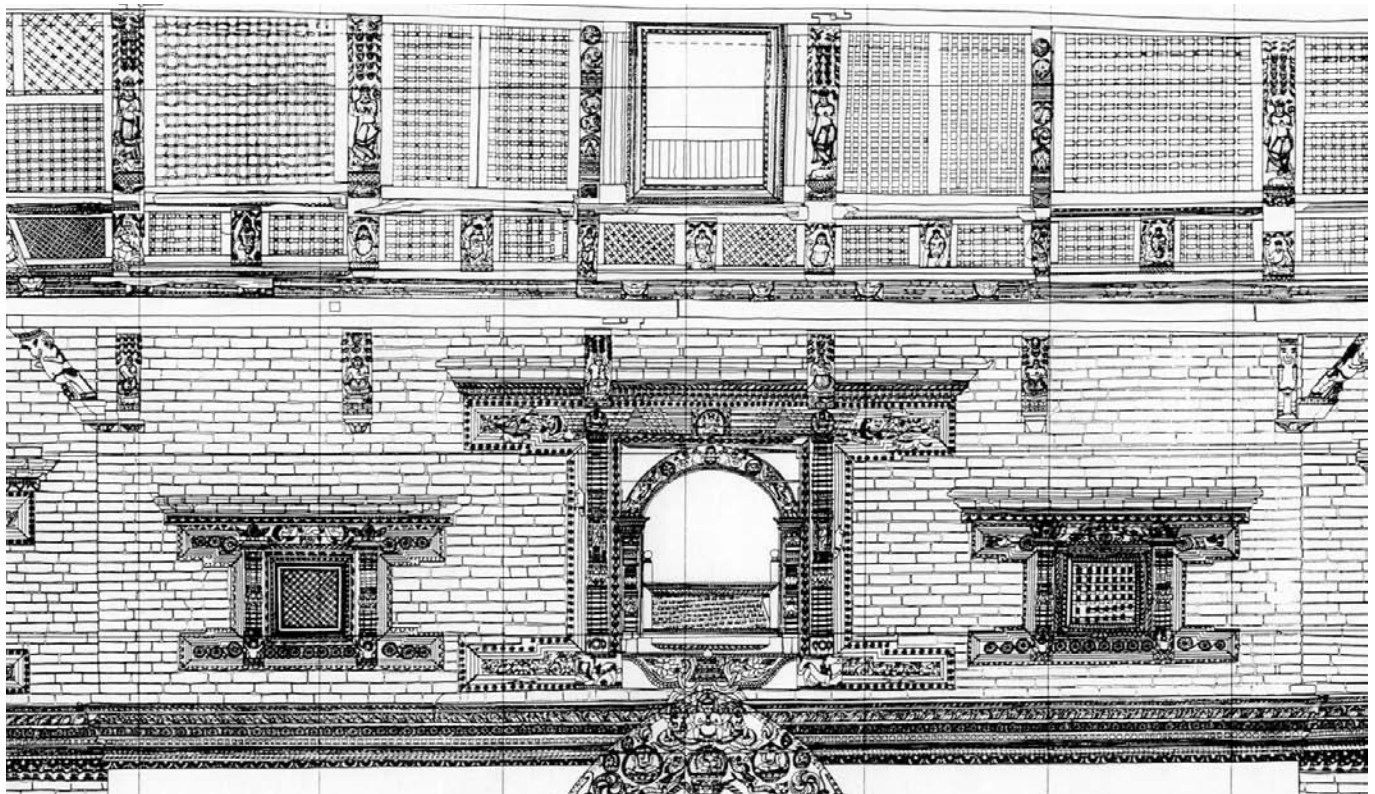


Fig. 5 Part of an elevation drawing of Sundari Chowk produced by the Nepalese team mobilised by Dr Bjonness (original scale 1:10). Courtesy of UNESCO.

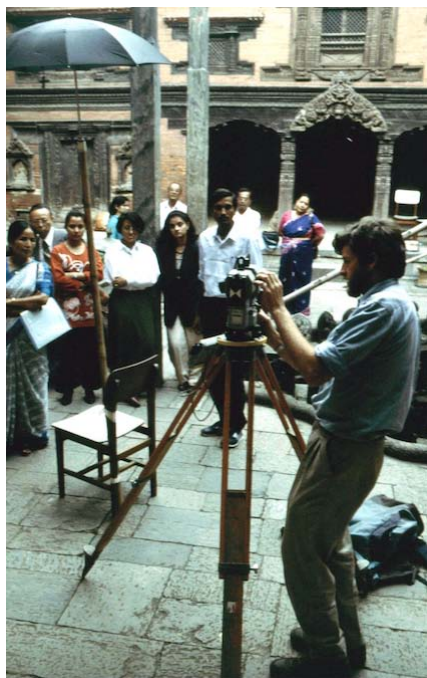


Fig. 6 The training workshop, demonstrating the use of the total station and data logger equipment bought for the project. Photo: Author.

temple towers of Agan Mandir, Taleju Mandir and Degu Talle by any other method. For the elevation survey, a two-stage approach was devised.

The totality of the elevations was surveyed to allow the production of 1:20 and 1:50 scale drawings to show overall

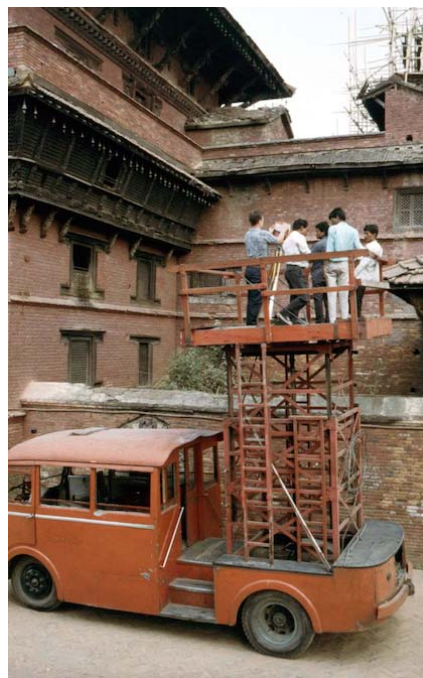


Fig. 7 Some of the photogrammetric survey of the high elevations was carried out from a lorry-mounted hydraulic lift on loan from the Kathmandu Trolley Bus Overhead Network. Photo: Author.

architectural design features, such as would be appropriate for repair and conservation work. Then, a series of much larger metric stereopairs were taken of each individual feature, which would permit the production of 1:5 scale detail

drawings of the type needed for exacting restoration or indeed replacement in the event of a disaster.

No plotting was carried out from these stereopairs. Essentially the photographs were the record (Figs. 7 and 8).

Scientific documentation and development control

The final plenary session of the professional seminar entitled 'Innovative Conservation of Cultural Heritage in Nepal' concluded with a discussion of the role of scientific documentation in the establishment of effective systems of planning control and in the implementation conservation projects. It was emphasised that apart from the palace buildings, the Patan Durbar Square Monument Zone included many hundreds of other structures of great importance to the integrity of the site, and that scientific documentation should play a primary role in informed decision-making within the planning system to ensure appropriate management and preservation of these buildings as well. The suggestion was also made that the computer-assisted recording system established for the Patan Durbar project could be utilised for the creation of a textual and graphical database for the Monument Zone, and subsequently elsewhere in the Kathmandu Valley World Heritage Site. It was further emphasised that such documentation

schemes should be linked to the creation of a Development Control Unit to monitor the World Heritage Site (Fig. 9). In 1975, a protective inventory of sites and monuments in the Kathmandu Valley was published with the hope that this would form a legal document to assist in protecting cultural heritage (Pruscha 1975). Ten years later, the urgent need for the enhancement of this inventory as the basis for future conservation policy was being stressed (Sangachhe 1985). However, such enhancement only began following a recommendation from the joint review mission to Nepal in 1993 (UNESCO/ICOMOS 1993). In light of the Patan Durbar project and the need to accelerate enhancement of the protective inventory, delegates to the professional seminar put forward two proposals for the future use of scientific documentation:

1. That the Department of Archaeology in cooperation with appropriate international agencies should build on the experiences of the Patan Durbar project and prepare a computerised inventory of the whole of the Patan Durbar Square Monument Zone as a pilot project and as an essential tool for the preservation of the historic built environment through development control.
2. That the inventory should be enhanced by the acquisition of new material resulting from a rolling programme of proactive survey undertaken to agreed specifications and pre-defined recording levels.

Retrospective

As a result of the Patan Durbar project in 1994-95, survey and computer equipment was purchased and personnel trained in its use. With the further assistance of UNESCO, a Development Control Unit was established within the Department of Archaeology in late 1995, the core element of which was three national professionals trained under the project and a further three Development Control Officers. Funding was made available to support these posts until early 1997 and the training and infrastructure provided by the project was developed and expanded. Following completion of recording work on the palace, documentation of the remainder of the Patan Durbar Square Monument Zone continued during 1996, through developing links with the local municipality and the Patan Conservation and Development Programme (sponsored by UDLE/GTZ – Urban Development Through Local Efforts/German Technical Co-operation). Given the importance of the project as a potential model which could be replicated else-

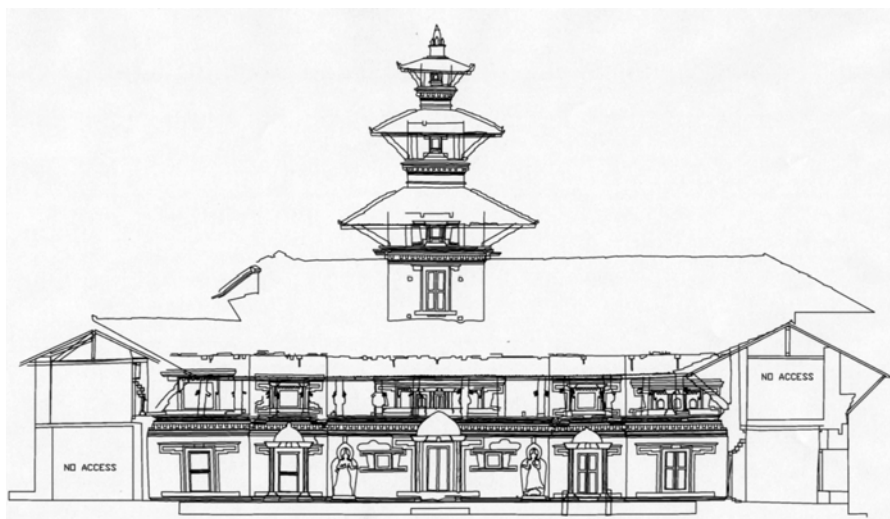


Fig. 8 An outline elevation and cross-section drawing of Mul Chowk and Agan Mandir based on instrument survey and photogrammetry (original scale 1:50). Drawing: LUAU. Courtesy of Oxford Archaeology North.



Fig. 9 An example of a building within the Patan Durbar Square Monument Zone which in 1994 was in urgent need of preservation. Photo: Author.

where, a symposium on scientific documentation was held at UNESCO headquarters in Paris in mid-1996 (UNESCO 1997).

In LUAU's final report and recommendations (HMG/UNESCO/JTFP 1996) it was stressed that the continued and appropriate employment of the recording team and its equipment within the Development Control Unit should be a high priority as they together represented an investment of potentially enormous importance to the future conservation of the Kathmandu Valley World Heritage Site. This recommendation was reinforced in UNESCO's Terminal Report on the project which stated that the Development Control Unit should be further strengthened with regular staff from the

Department of Archaeology (UNESCO 1997).

Unfortunately, serious under funding within the Department of Archaeology, coupled with the loss of several team members to better paid jobs outside of Nepal (mainly to China where their transferable surveying and computer skills were much valued), meant that momentum was lost. World Heritage Sites clearly have the potential to reduce poverty where projects generate employment opportunities (see Teleset-sky this volume). However, in Nepal, one of the poorest countries in the world, the economic situation was such that the individuals concerned were relatively quickly enticed to work outside the country and their experience and



Fig. 10 An example of the encroachment of housing development on the boundary of the Patan Durbar Square Monument Zone. Photo: Author.

skills lost before others could be re-trained to take their place.

Commencing in 2002, the Asia Urbs programme, an ambitious capacity building scheme funded by the European Union, paired Patan with the City of Chester in an attempt to reinvigorate and expand the former Development Control Unit (now known as the Heritage Unit) in the expectation that heritage would become a key driver for tourism. The scheme resulted in the appointment of Conservation, Design and Archaeology Officers, tripling the staffing levels in the Unit.

However, it appears this renewed investment may have come too late. Patan, it is estimated, has already lost 35% of its historic building stock in the last two decades, although current measures designed to eliminate the destructive encroachment of illegal housing and other works are beginning to take effect (see Thapa this volume) (Fig. 10). As for the World Heritage Site in general, the lack of development control within the various Monument Zones was a reason for the Site being officially recorded on the World Heritage in Danger List in 2003. The situation does not seem to have improved since. In a recent tourism survey of World Heritage Sites, compiled the National Geographic Center for Sustainable Destinations and George Washington University, the Kathmandu Valley came bottom, scoring 39/100, being described as polluted and scarred by modern concrete buildings.

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A great debt of gratitude is owed to Dr Hideo Noguchi (former UNESCO Chief of Section for Operation and Training for Asia/Pacific and Europe), Mr Khadga Man Shrestha (former Director General of the Department of Archaeology) and his staff, and Mr Yoshida, former Ambassador of Japan in Nepal. Although this paper is largely concerned with the application of scientific documentation, the work was not undertaken in isolation but as an integral part of a multi-disciplinary conservation project. The success of this approach is due to the enormous contribution of the project manager, Mr David Micheltore (former UNESCO ITA). I am also grateful to my former colleague, Mr Jamie Quartermaine, at LUAU (now Oxford Archaeology North), for access to the project archive.

Notes

¹ The NIT study contains an incomplete series of 1:400 and 1:200 plans, 1:100 elevations and 1:50 cross-sections. Restricted funds and a tight schedule (the entire survey and study of the Patan buildings was completed in under ten days) led to compromises in the accuracy of the survey control system. While admitting to this, the published report does not offer any method statement as to how the drawings were generated. It simply states that the decision was taken to use a stereometric camera in conjunction with hand-measured control (NIT 1981: 2). Despite this claim, the drawings appear to be the product of rectified photography rather than photogrammetry.

² Keshav Narayan Chowk was not included as it was the subject of a separate restoration project funded by the Austrian Institute for International Cooperation.

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It was in this latter post that Jason acted as a UNESCO Consultant for the management of the scientific documentation and training programme associated with the Patan Durbar Square project in Nepal.

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The Wisdom of the Earth - La Sagesse de la Terre

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«Statues may seem alive, but when you ask something they do not reply»

Jorge Luis Borges, *Seven Nights*, N.Y. 1984

Brancusi spent only two months chez Rodin's workshop in Paris. On 27 March 1907, aged 31, he moved to 54 rue de Montparnasse, where he started to work on his own by the technique of directly carving in stone. The two statues he created the same year were entitled *The Kiss* and the *Wisdom of the Earth* by Brancusi himself. Both statues are miniature works. *The Kiss*, carved in stone, has the dimensions of 28 x 26.1 x 21.8 cm and nowadays is exhibited at the Art Museum of Craiova while the *Wisdom of the Earth*, carved in crinoid limestone, has the dimensions of 56.5 x 16.5 x 24.9 cm and is temporarily exhibited at the National Art Museum of Bucharest. Although both statues have the same status of pioneer's work, their public perception, level of understanding and historical position are much different. Brancusi's *Kiss* displays his original philosophy of creation up to the smallest details, without bearing any influence of Rodin. On the contrary, the *Wisdom of the Earth* appeared on world's stage as a strange, peerless object, as if unexpectedly fallen from the heaven, bearing only a mysterious name that Brancusi never explained. Overlooking that Brancusi was actually a genius and not an ordinary stone cutter, some critics accused him of obstinacy. It is the aim of this paper to disclose this apparent puzzle, after 108 years of confusion.



Fig. 1 The Kiss, 1910.



Fig. 2 The Gate of the Kiss, 1937.

The perfect plastic art of Rodin's homonymous statue was a challenge to Brancusi. From the very beginning, Brancusi has chosen for his replica an orthogonal system of gravitationally oriented Cartesian axes. That was the initial moment that con-

nected the statue to the Universe. Then, the plane containing the vertical axis of the Cartesian system was chosen as a plan of symmetry for the two partners who implicitly received identical shapes and sizes. This way Brancusi succeeded a double mirror-

ing effect that Topology calls congruence. Thus, the kiss becomes transcendental in both horizontal directions. In addition, the arms of the two partners, rigorously located by the sculptor in parallel horizontal plans, become free of gravity, which confers maximum intensity to the embrace that supports the kiss. By chance, the following year Brancusi was asked to produce a funeral monument for the grave of Tania Rachevskaia, a Russian girl who committed suicide for love in 1908. Then he extended the original statuary group from busts to full bodies, but sitting not standing. The monu-



Fig. 3 The Wisdom of the Earth, 1907.

ment carved in limestone with the dimensions 89,6 x 30 x 20 cm can nowadays be seen in the Montparnasse Cemetery, Paris (Fig. 1). After thirty years since his first statue, in 1937, Brancusi carved 40 identical images of his full *Kiss* on the travertine plates of the monumental *Gate of the Kiss* at Targu-Jiu, Romania (Fig. 2). The competition between the two sculptors concluded with the feeling that Rodin's *Kiss* remained perfect but ephemeral while Brancusi's became a symbol, and therefore eter-

nal. From the very beginning of his creation, Brancusi understood that gravity is like the soul of matter and he will never deny his creed.

The Wisdom of the Earth statue arrived from Paris in 1910, with the intention to be exhibited for the first time at the Artistic Youth Salon in Bucharest; however, it roused contradictory opinions from very beginning (Fig. 3). The most disputed was the statue's head. Local press wrote that the statue "disturbed the current notions of beauty" (Brezeanu, 2005). The public interested in art was quickly divided into two parties, the avant-gardists who supported the admission of the statue and the conservators who objected it. Finally, the statue was exhibited, but criticism never ceased. It was successively written that the statue represented a pagan figure from the Thracian epoch or a strange divinity found under ancient ruins, its eyes looking into the mysterious inner infinity or suggesting the essence of Mother-Earth. It was also suspected that Brancusi had been inspired by Paul Gauguin's pastel Breton Eve created in 1889 and exhibited at the Art Museum in San Antonio, Texas (Bach, 1995). The controversies around the *Wisdom of the Earth* amplified as Brancusi's worldwide fame increased. In the meantime, the statue travelled and, only between 1957 and 1995, was successively exhibited in Milan-1957, Venice-1960, Paris-1961, London-1966, Bucharest-1967, Philadelphia and New York-1969, Chicago, Bucharest and the Hague-1970, Bucharest and Craiova-1976, Paris and Philadelphia-1995. Paradoxically, the genius of Brancusi was praised everywhere while the confusion about the statue's meaning deepened. The interest in the statue

increased so much that in 2005 a deferential book was consecrated to it in New York. In that book, the Greek appellative of Sophrosyne, with an emphasizing meaning, was added to the original name of the Wisdom of the Earth (Pogorilovschi, 2005). Finally, according to the mass media, several years ago an international authorized company in Paris evaluated the statue to a fabulous amount of money, without disclosing the criteria used in their analysis.

It is easy to observe that all this bewilderment that lasts for longer than a century is due to an initial error. From the very beginning, it was assumed that the statue represents a woman, which is false. Nobody and nowhere ever hesitated to believe that Brancusi created anything but a female by stone carving, especially after the overwhelming success of his *Kiss* in the competition with Rodin's. The fascination with the statue is so strong that probably even Schopenhauer himself would have accepted that his philosophy on ugliness was right. However, not even the Sphinx in Giza, Egypt, does represent a female, but a lioness with a female head. In the case of this statue, the word wisdom is an attribute of human brain, and the brain is located in the head. On the other hand, Brancusi named it *the Wisdom of the Earth*, not of the head. By comparing the two binominal sentences, one finds the equality

the wisdom of the head = the wisdom of the Earth → the head = the Earth

that satisfies Euclid's first axiom. Therefore, the statue should be regarded as a sphinx consisting of a fe-

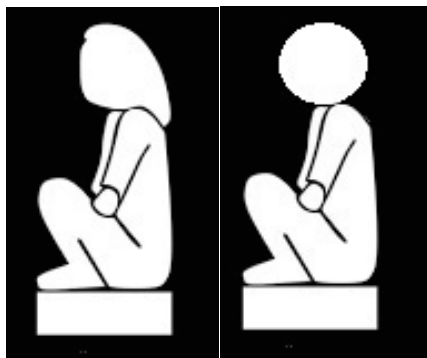


Fig. 4 The Statue; Fig. 5 The Sphinx

male body symbolically supporting the Globe (Figs. 4-5).

Both the Globe and female body were accordingly stylized to plastically suit one another.

The female body was preferred to the male one because it is endowed to give life. Also, the idea of a cosmic object supported by a human body is not new. In Greek Mythology, the Titan Atlas supports the celestial vault for thousands of years. In the case of the statue in discussion, Brancusi humanized the Globe. In addition, the female body was accurately shaped according to the laws of equilibrium in the gravitational field. The back of the body was perfectly squared with the statue base,

while the head was displaced forward so as its weight fell in the third half of the base. Once this precise concept of creation was understood and accepted, discussion can advance to wisdom. It cannot be the real wisdom of the Earth, but the first of the two essential properties of the matter, gravity and inertia, discovered by Isaac Newton in London and published in *Philosophiae Naturalis Principia Mathematica*, 1687. The Earth is surrounded by its gravitational field which in each point in space assumes certain intensity and thus receives its oneness in the Universe. The mass of a material point or body, associated with the intensity of the gravitational field, generates the gravity force. This is an interaction force or the reciprocal attraction between the assumed point or body and the Earth. Gravity is the weakest of the four fundamental interactions of nature, but with the largest range of action. The other three forces are electromagnetic, nuclear weak and nuclear strong. Their nature is well known and they are easily controlled. On

the contrary, the nature of gravity force is unknown and that is why a unified “Theory of everything” could not be formulated (Hawking, 2005). For this preliminary presentation, it would of interest to know whether there is any connection between Brancusi’s Sphinx the *Wisdom of the Earth*, and the Egyptian one. The period when the Sphinx at Giza was erected is unknown. The version that King Khafre, the son of Khufu or AKA Cheops has completed the Sphinx in the period 2558-2532 BCE, after the Great Pyramid 2580-2560 BCE, is not confirmed. However, it is certain that, between the lioness paws of the Sphinx at Giza, a large stone was discovered carrying the inscription “This is the Splendid Place of the First Time” (Fig. 6). The First Time, or *Zep Tepi*, was a mysterious expression the Egyptians used to allude to *the beginning of time*. Robert Bauval has managed to determine that *Zep Tepi* occurred in the year 11,451 BCE when the Milky Way was parallel with the Nile and mirrored in its waters. Therefore, the Sphinx at Giza is a monument to the first time when the Four Elements, water, soil, air and fire, were locked into one place, with the result that matter finally became solid. Plato (428-348) BCE described that event in his dialogue *Timaeus* in 360 BCE as “the instant when consciousness was fixed in solid matter”. It marked that point when “*after wave upon wave of emanations from the cosmic mind, solid matter as we know it today was finally formed*”. That is why it is perhaps the greatest icon of the ancient world (Black, 2010). The Egyptian Sphinx was later adopted by Greek Mythology as a monster consisting in a winged lioness with a female head. This



Fig. 6 The Egyptian Sphinx at Giza.



Fig. 7 The Greek Sphinx with Oedipus.

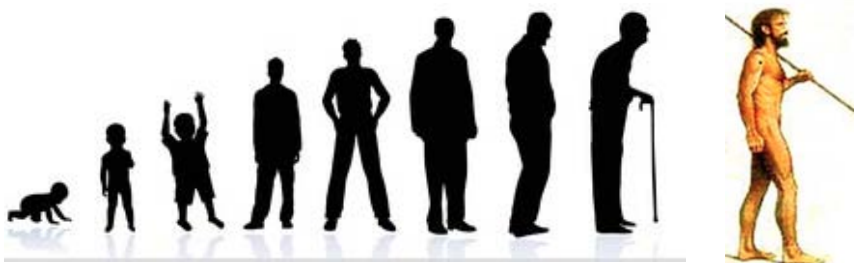


Fig. 8 The three steps of life; Fig. 9 Bipedal adult.

Sphinx is said to have guarded the entrance to the Greek City of Thebes (Fig. 7). From that position, she asked all passers-by the most famous riddle in history: "Which creature has one voice and yet becomes four-footed and two-footed and three-footed?" She strangled and devoured anyone unable to answer. Oedipus, the King of Thebes, quickly solved the riddle by answering: "Man who crawls on all fours as a baby, then walks on two feet as an adult, and then uses a walking stick in old age" (Fig. 8). Oedipus answer

was correct indeed, but it seems to come in contradiction with Newton's Law of equilibrium. In adult age, humans are supported in only two points, which is not enough for their stability. For static stability, at rest, a 3D body needs at least three non-collinear supports, and for dynamic stability, in motion, four such supports. The answer to this puzzle was given by Archimedes: it is gravity that provides the additional support for static and dynamic equilibrium (Fig. 9). That is why gravity is so much

praised by humans and so many monuments, under different shapes and sizes, were devoted to it during the centuries. Therefore, Brancusi's Sphinx *the Wisdom of the Earth* and the Egyptian Sphinx share the same magic gravity, for their common purpose, which is the equilibrium with its benefic state, the stability.

In 1913, Brancusi devoted a small white marble statue to Narcissus, now exhibited at the Art Museum of Paris (Fig. 10). Brancusi was conscious of this sad and, at the same time, paradoxical legend. All the boys in the world are beautiful, and therefore none of them is motivated to commit suicide only for the reason of own beauty. Considering the legend from the viewpoint of physics, it seems that in fact Narcissus discovered that his own image mirrored by the shimmering water was immaterial and therefore free of gravity, (Fig. 11). Only he, the material one, was subjected to the permanent action of gravity being prevented to move and act as a free person. That is why he decided to find his freedom by committing suicide. Plato also drew attention that transcendence from material life to the immaterial one occurs by mirroring. Since then, the call for liberation from the compulsion of gravity took large proportions, becoming a true Narcissus Syndrome. It is strange, however, that the same gravity which is praised in Oedipus Legend is blamed in the Narcissus one. This duplicity of the character is typical for human nature.

The Biblical Legend of Adam and Eve is mostly paradoxical by bringing innocent people under the tree of knowledge and then proclaiming that their access to knowledge is forbidden. Since the 17th century, Newton had proved that there was

nothing else hidden in the incriminated apple tree but the knowledge of that time about gravity, namely the free falling down of material bodies. Why should people be kept afar off that knowledge? Is gravity top secret? Since the end of the 20th century, the puzzle has started to intrigue scientists. Brancusi devoted, with his sincere compassion, a wooden statue of 239.4cm in height to the Legend of Adam and Eve, so that it may always be regarded by anyone upwards. The two partners' heads, with open mouths as if shouting "not guilty" and faces expressing wonder for their unexpected expulsion, were rigorously superposed on the same vertical axis on which their bodies were melting into each other, so that a thin trunk resulted. Such shaped, the statue displayed the total solidarity of Adam and Eve in facing the accusation of sin with dignity. Since 1921, the statue has been exposed at the Solomon R. Guggenheim Museum in New York City. Brancusi remained consistent in his interest for gravity, in spite of the prohibition around the subject (Fig. 12)

It is now obvious that Brancusi was obsessed with gravity (Sofronie, 2001). He felt the gravity of matter like Vincent van Gogh saw the nebula on the starry skies. All creations by Brancusi are based on his intuition of genius. Intuition means knowledge behind logic and consciousness of the incognizable without any explanation. Intuition is answering only to existential questions; it succeeds there where reason fails. Finally, intuition comes from soul not mind and is always acting spontaneously. This explains why Brancusi has won so many hearts around the world. His genius conferred him singularity. Often, his language seemed strange



Fig. 10 Narcissus 1913, Paris.

or incomprehensible, but in fact it was the inner voice coming from one of the few with the gift of genius (Sofronie, 2015).

Coming to the end of this brief presentation, one may conclude that the Egyptian Sphinx is a memorial devoted to a crucial event that happened in the past and marked the history of humankind. In spite of its miniature dimensions, Brancusi's statue *the Wisdom of the Earth* is also a Sphinx like the Egyptian one, but with a different message. The message that Brancusi carved in that piece of crinoid limestone has not been decrypted yet and it is not the author's intention to make any speculations here and now. It is, however, certain that Brancusi's message is directed to the future and refers to human consciousness therefore it has a premonitory nature.

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Fig. 11 Mirroring effect.

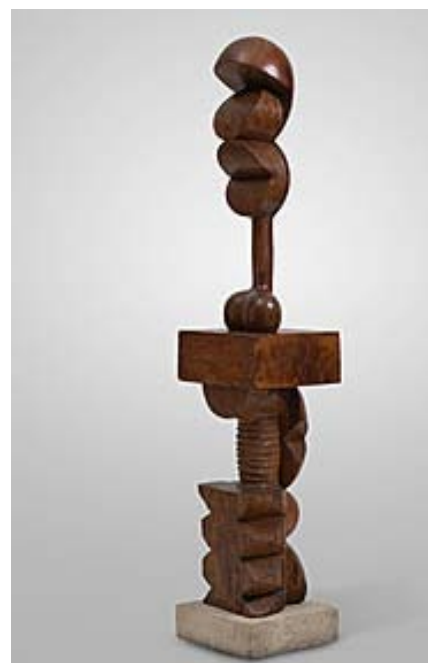


Fig. 12 Adam and Eve, New York.

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Conservation Engineering Toolbox: Practice Codes and Standards

Donald Friedman Old Structures Engineering
David Yeomans

The purpose of building codes

The purpose of building codes is to ensure that construction meets the standards required by public authorities normally to ensure the health and safety of both the building's users and the public. In this chapter we are concerned with structural codes which are designed to prevent structural failure. Such codes in general specify the loads to be carried, which will be dependent upon the use to which the structure is to be put, the allowable stresses in the materials, or the limit states of members, and may in some cases specify the method of design. Code provisions vary over time, and vary from country to country. They sometimes vary within a country, but a number of aspects are common to most current structural codes.

Present building codes are focussed on new construction. The provisions on allowable stresses or other limit states, which are usually prescriptive, assume modern materials and are usually defined in terms of material standards set by standards-setting authorities.¹

This presents a problem when the materials used in an historic structure are no longer in use and hence are not dealt with in current codes. There is also a problem when the forms of construction are not those envisaged by the codes, such as French colombage or German fackwerk. However, a more general problem is that the requirements of a current design code may be in conflict with the requirements of historic preservation suggesting interventions that would result in loss of historic character. The ISCARSAH *Principles* state that:

Where the application of current design codes would lead to excessive interventions that would involve the loss of historic fabric or historic character, it is necessary to clearly describe the situation and to explain how adequate safety is provided by alternative means.

Therefore the conservation engineer has a dual role. He/she must ensure that the structure is safe while at the same time avoiding any loss of historic character. That means understanding the nature of the historic character.

The purpose of this chapter is:

1. to illustrate where and how modern codes may be in conflict with the requirements of historic preservation,
2. to show where they may be inadequate to ensure the safety of an historic structure,
3. to discuss what other means may be used when present codes are of questionable value,
4. to show how earlier codes may provide valuable data,
5. to provide the kind of guidance for the ensuring the safety of historic structures that present-day design codes provide for new construction.

Requirements for compliance

Clearly there is no requirement for existing buildings to be adapted to meet new code requirements as they are introduced. This means that existing structures rarely comply with existing standards. That does not mean that they are any less safe than when they were first built.

Modern building codes are a combination of prescriptive and goal-oriented provisions, based on both empirical data and directed research. Design codes have been written to ensure that new structures are 'safe,' with safety defined as having a carrying capacity greater than the expected loads. Both the loads and the material properties are specified by codes. Defined in this way, safety is a con-

struct of the codes, dependent on code-specific loading and material properties, and on the specific model of structural action chosen by the engineer performing the analysis. Code provisions vary over time, from country to country, and sometimes within individual countries, but there are certain patterns that are typical of the structural provisions of most current codes.

When only repair work is undertaken there should be no attempt to bring the structure up to modern code standards. The ideal should be to repair the structure in such a way that it performs in the manner in which it has successfully performed in the past. That is not always possible and it may only be possible to give the structure a helping hand. Some assessment is then required of the load capacity. Compliance with current building standards is normally only required when there is a change in use of the building or substantial alterations.

Types of structural code

Codes may specify the form of construction to be used. That was typical of many earlier codes which assumed basic forms of construction and specified forms and details which were known to give satisfactory performance.² The equivalent in conservation work is that a code-specified form of construction may result in the loss of historic fabric. It is generally not possible to comply with all provisions of such prescriptive codes.

The alternative is that the code specifies a required level of performance in terms of the loads to be carried leaving the engineer to demonstrate compliance. In such circumstances the engineer may either be able to demonstrate compliance or may need to seek waivers.

A common modern code provision that is the key to the discussion that follows is that designers are allowed to use their judgement in lieu of specific code provisions. For example, there is the permission in EC0, §1.4 to use alternate design methods as long as "the alternate rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability which would be expected when using the Eurocodes" or the IBC provisions that "any system or method of construction to be used shall be based on a rational analysis in accordance with well-established principles of mechanics..." (§1604.4) and "An existing building...which does not comply with the requirements of this code...shall not be altered or repaired in such a manner that results in the building being less safe or sanitary than such building is currently" (§3410.2.4). In general conservation engineers may rely upon 'first principles' because they are not culturally based.

Conservation Standards

Many countries provide legal protection for historic or heritage structures. These take the form of 'conservation standards', which generally prohibit or restrict interventions that would affect the historic character of the fabric. Many of these standards are based, wholly or in part, on the 1964 "Venice Charter for the Conservation and Restoration of Monuments and Sites," which provided the first uniform international guidelines on which some national standards have been based.³

These standards may either take the form of an enforceable code, or may simply be used as the basis for review of proposed work. They may be applied at the local or national level, depending upon the historical significance of the property in question.

Existing conservation rules typically do not address structure, but are focused on issues of historical, cultural and social importance. Moreover, many conservation professionals are unfamiliar with the history of structural design and therefore may be unaware of the historical significance of a particular structure. They are more frequently unfamiliar with the principles of structural engineering. In these circumstances it may be necessary for the conservation engineer to provide guidance on both the historical value of the structure and the effect of any intervention on its historical value. Note also that because many of those applying structural codes are unfamiliar with the methods of building conservation the conservation engineer also has the responsibility to explain the effect of conservation issues on structural choices available to the project team.

Code compliance

In order to understand the problems associated with the application of current structural codes we may usefully compare the process by which the codes are applied in new construction with their application in historic preservation projects. For an engineer, designing a new building is easily described: the loads, the member analysis methods, the allowable stresses, and even the preferred details are found to some degree in the locally-governing code and its related material standards. The procedure for an engineer analyzing an existing new building follows these same steps. These steps are:

1. Determine the loads which the structure is required to withstand. These divide into:
 - (a) the self weight of the building fabric
 - (b) the superimposed loads comprising
 - i. occupancy load
 - ii. environmental loads, such as snow and wind loading
 - iii. earthquake loads
2. Determine the load path within the structure for the different possible load combinations
3. Determine the size of members and specify the material properties necessary to achieve the required performance standard.

For an historic building the following steps are appropriate.

1. Determine the loads which the structure is required to withstand:
 - (a) Determine the current-code load requirements.
 - (b) Determine load history as best as possible which will be related to the history of building. Note that usage may have changed several times since construction and the loads expected for a given usage may also have changed since construction. Changes in use, exceptional loading (significant storms or earthquakes), and periods of abandonment must also be examined.⁴
 - (c) Analyze physical conditions to determine if any portion of the loading required by the current code is unrealistic. For example, code wind loads are not going to be applied to a small historic buildings surrounded by larger, equally historic buildings, a situation common in many city centers.
 - (d) Analyze governing codes to determine if any portion of modern loading is excluded. For example, historic buildings may be exempt from analysis using seismic loading if they are not being altered.
 - (e) Combine the loads from the previous steps to create design loads.
2. Determine the load path within the structure:
 - (a) Determine materials present.
 - (b) Determine structural systems and possible load paths.
3. Analyze the structure given the loads and materials:
 - (a) The provisions of the current building code or materials standards may be applied if they are applicable to the materials and systems present.
 - (b) If the current governing building code or materials standards do not address the material and system present, consider whether any previous versions of that code address the material or system.⁵
 - (c) If no applicable codes or standards of the construct era exist, consider whether there are current codes or material standards that address materials and/or systems of similar characteristics.⁶
 - (d) Combine the available code information from the previous steps to determine material properties
 - (e) Analyze the structure, using loads and material capacities determined above.

Note that code requirements have been drawn up to cover general situations whereas conservation

engineers are dealing with very specific situations and may therefore be in possession of specific information which was not available to those drafting the code or designing the building originally. This comment applies at a number of stages in the design or assessment process.

It is clear from the quotation from the *ISCARSAH Recommendations* that the conservation engineer is not always attempting to meet code requirements. And because that may well be so in a minority of cases, the term safety compliance will be used instead of code compliance.

Because a conservation engineer is not following the normal procedure he/she has a responsibility to document clearly, beyond the normal requirements. A clear description of the safety review process used on a project is necessary for several reasons. First the analysis cannot be adequately performed if the all those involved do not have a clear understanding of the safety issues and agree to the process to be adopted. This requires a written statement of intention and methods to be adopted by the conservation engineer.

Second, similar issues will almost certainly exist in the non-structural portions of modern building codes, so that a description of the structural code review may be of use to the entire project team. It is usually not necessary for different disciplines to coordinate their approaches to codes, but if it is possible it simplifies review by code officials and therefore simplifies the process of gaining approval. Finally, building control officers, by the nature of their job, are focused on code compliance and, despite their knowledge with current codes and standards, may be unfamiliar with obsolete structural codes or buildings. If a conservation project relies on exemptions or interpretations of current codes, this must be explained to the reviewer.

Loads

Occupancy loading

Occupancy loading is determined by general building use and applies to all floors within the building. Offices may typically be designed for a floor load of 2.5kN/sq. M (50lbs/sq.ft). However this allows for some areas within the office to be used for storage. If it is known that rooms will not be used in this way then much lower floor loads may be assumed in assessing the capacity of an historic floor. Note also that restrictions may be applied to the use of an historic building which are determined by the building's strength – thus strength determines use rather than the other way round.

The loads now being applied to an historic structure may be significantly different from those for which the structure was designed. This is often because there is to be a change of use but might also be because current loading requirements are different from those used in the past. For example, floor loads in earlier building standards were typically much greater than those in use today. Code requirements normally determine the superimposed loads and the required level of performance. They may also establish the methods by which the level of performance in service is assessed. Setting aside the fact that there may be a degree of iteration in design, the differences when dealing with an historic structure are:

The load history may be significant in an existing building. This may be because there has been repeated loading which has caused fatigue effects or because there may have been excessive accidental loading that has adversely affected the structure.

The load history may provide one with a degree of confidence in the capacity of the structure.

Wind loads

Wind loads are statistically determined and in principle survival over a sufficient period of time should be sufficient to guarantee adequate future performance. The caveats are that there shall have been no substantial changes to the structure that would affect its stability. There must also have been no changes to its surroundings that might increase wind loads. For example in rural settings shelter belts of trees may be eliminated by changes in agricultural practices. In urban settings buildings on adjacent lots may have been built or demolished.

Another affect is that climate change is resulting in increased wind loads in some parts of the world and this needs to be taken into account.

Snow loads

Snow loads are similarly statistically determined and survival of the building may be sufficient demonstrations of safety. However, replacing of the roof covering or the adding of insulation may change the weight and so require a reassessment of the roof structure.

Note that snow loading is now based on much longer term measurement of snowfall than that used in old codes. In many cases the modern ground snow load is less than that used in old codes, although this may be offset by modern provisions for calculating drift loads.

Earthquake loading

In seismic zones, survival of a building over a period of time is no guarantee of future survival; survival of an earthquake during the life of the structure is rather a matter of concern. Future earthquakes may be of a higher magnitude and earlier earthquakes may have weakened the structure. Thus in earthquake zones structures require a full survey and earthquake assesement. However that does not mean that they must comply with modern code requirements. The task, as always, should be to ensure that they will perform in a satisfactory manner under the specified earthquake loading rather than complying with specified standards of construction.

Material properties

Material properties may also be set by code requirements or defined within national standards which for this purpose may be treated in the same manner as design codes. Properties are assumed during design when structural members do not yet exist. The properties are specified in contract documents and controls put in place to ensure that these properties are provided.

In an existing building the properties need to be determined, often by measurement of the structure itself. In some cases the structure may have been built to standards in place at the time of construction and reference may be made to those standards (see below).

However even in such cases a measurement of the material properties may show that they differ significantly from the specified values. The structure might also include manufactured components, including iron and steel rollings, that were made to a given specification to which reference may be made.

A more common situation is where there is no such data and properties need to be obtained by measurement of the structure itself. In such circumstances demonstrating safety compliance may also include agreeing a method for determining material properties.

Masonry

Old clay masonry was fired at lower temperatures and with less-even heating than modern brick, and therefore has more variable and usually lower compressive strength, as is reflected by changes in code allowable stress values.

Timber

Current methods for grading timber are designed to maximize yield of commercial supplies. The resulting grades produce step values for material properties. Grading of in-situ timbers by the same methods, even if possible, may result in the condemnation of structurally adequate timbers because they fail to meet the requirements of a particular grade and so must be assigned to a lower grade. A more subtle means of determining structural capacity of in-situ timbers is required. At the time of writing a method of grading timbers in the US has been published⁷ and work on a European standard is in hand.

Iron and steel

Where the source of the rolled iron and steel can be identified from rolling marks the manufacturer's published information may be used as the source for material properties. There may either be historic documents originally produced by steel manufacturers or more recent summaries of such documents.⁸

Reinforced concrete

The relationship between water-cement ratio and the strength of concrete was not established until the work of Duff-Abrams in the late 1910s and then not universally applied. Note also that aggregates sometimes used caused corrosion of the steel. In these circumstances the taking of samples for testing is the only reliable method for determining the structural properties of the concrete. Exposure of the steel to determine its condition may also be required.

Design method

Typically a designer will be required to submit a design for a new building for checking to ensure that it meets the code requirements. However, the designer will need to explain to the checking authority the general structural scheme that has been adopted, in other words how the loads are assumed to be brought to the ground.

A general principle which may be applied in new design is that if there is a path by which the loads may be brought to the ground that is within the capacity of the structural members, then the structure will be safe no matter how the loads are actually brought to the ground. This takes care of the degree of uncertainty that frequently exists in any structural modeling. Providing the checking engineer can accept the structural scheme that has been proposed, then checking for code compliance can proceed.

The allowable stresses, required loads, and even the types of structural elements regulated in codes are all based on models which approximate to reality. Engineers and code officials trained only in modern construction may confuse the model with reality and one which ignores significant aspects of historic buildings.

Specific aspects of the real structure that may be overlooked include the use of mass masonry, arches, and vaulting; the use of wood-framed bearing partitions within masonry-wall buildings, traditional wood jointing, and load-sharing with cladding; the conservative nature of past designs and past codes; and practical restrictions on live load. Current models are unable to cope when there is no clear distinction between structure and non-structure.

Such an approach is not necessarily sufficient when dealing with an historic building. That is because, while the engineer may be able to identify a safe load path among the alternatives present, the actual load path may result in the failure of a member which, while not fatal to the safety of the structure, results in unacceptable loss of, or damage to, historic fabric. It is therefore incumbent upon the conservation engineer to consider alternate load paths.

The use of historic codes

An early stage in the assessment of an historic structure is to carry out a desk study to gather those documents relevant to the history and condition of the building. This will produce such information as the date and original purpose of the building and records of any changes that it has been subjected to.

The results of the desk survey will supplement the results of a physical survey of the building. The desk survey should include information on the building and design codes in force at the time of construction. These will typically differ from modern codes. Some of these differences have already been referred to but they include:

- Design floor loads have generally been reduced with improved knowledge of typical loads

found in practice.

- Allowable stresses have changed. This may be because of improved understanding of the material's performance and can result in higher allowable stresses than those originally assumed in design. An example is the allowable stresses in structural steel which have been increased. As there has been no change in the true properties of the steel the result is that the capacity of the structure can be assumed to be higher than its original design capacity. In contrast the allowable stresses may have been increased because of improved workmanship. This is the case with reinforced concrete so that the improved allowable stresses have responded to a real improvement in the properties of the materials.

The value of historic codes is that they provide data that cannot easily be obtained by inspection. This might be as simple as a specification of sizes of members that cannot easily be measured. However it might include descriptions of the material specifications to be used or the load conditions to be designed for. Clearly this only applies to those structures built sufficiently recently for there to be codes. However a number of patented systems of construction preceded the development of codes and they included construction specifications which determined the standards of construction and so provide guidance on the present standard of performance to be expected.

Clearly if an historic structure can be shown to comply with modern code requirements there is no problem. This may not be the case if data required to carry out a code assessment cannot be obtained. This might be so when material properties are unknown or when the performance of connectors is unknown so that the structure cannot be adequately modeled. In such cases conservative assessments might be made of the material properties. This is not always successful as it might result in a gross underestimate of the structure's capacity. Alternatives are then to undertake some testing of the material in question in order to obtain an improved assessment of the values in question, which may then be applied in a revised assessment or to undertake a load test of the structure. Load testing is equally valid when modeling of the structure suggests non compliance with the code when its history indicates long-term satisfactory performance.

In some cases the present code does not apply to the structural form we are trying to assess or the code suggests that the structure is inadequate when experience suggests otherwise. In such cases the ISCARSAH *Recommendations* require that an evaluation of the structure be carried out based upon fundamental engineering principles.

Notes

¹ Such as the American Society for Testing and Materials (ASTM) or the British Standards Institution (BSI).

² An example is the London Building Act which assumed load-bearing brick masonry and specified the thickness of external walls for a given height of building. The effect was to hinder the introduction of framed buildings.

³ E.g. in the United States "Secretary of the Interior's Standards for the Treatment of Historic Properties".

⁴ For example, the 1916 "Black Tom" explosion at a munitions depot facing New York harbor caused permanent damage to nearby buildings, including some, such as the Central Railroad of New Jersey terminal in Jersey City, that are now designated landmarks. The explosion caused a one-time extreme loading whose effects can be seen today and must be included in an analysis of the adjacent buildings.

⁵ For example, local (city) building codes in the United States up until 1910 typically contain provisions for analysis of cast-iron columns, and over time the changing versions of these codes typically show evolution of experience and provisions.

⁶ For example, the analysis of cast-iron columns resembles that of slender, unreinforced masonry piers.

⁷ Ron Anthony's standard.

⁸ AISC and the ISE publication on historic sections.

Documenting Structures of Built Heritage

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Introduction

Documenting is a necessary step in the process of Built Heritage Care. According to the CIPA Principles¹, recording is one of the principal ways to give meaning, understanding, definition and recognition of the values of the cultural heritage». Protection of values is arguably the main object of cultural heritage conservation. UNESCO World Heritage Sites are for instance chosen on the basis of their «outstanding universal value»².

As a specific discipline concerned by cultural heritage conservation, structural conservation also has the duty to help protecting values. The values of buildings seen as structures certainly do not stop at the surface. The "anatomy" of the fabric, its materials and structural elements are essential. Indeed, as it is stressed in the ISCARSAH document³:

«the value of architectural heritage is not only in its appearance, but also in the integrity of all its components as a unique product of the specific building technology of its time», «the distinguishing qualities of the structure and its environment, in their original or earlier states, should not be destroyed», «each intervention should, as far as possible, respect the concept, techniques and historical value of the original or earlier states of the structure and leaves evidence that can be recognised in the future».

Dealing with values is not straightforward. First of all, and the question will be further elaborated below, they are often difficult to measure. Moreover, as already noticed by Alois Riegl⁴, values of "monuments" are many; they often have contrasting requirements and may be weighted differently by the stakeholders. In relation to structural aspects, one set of contradictory requirements arises directly:

- 1) conservation tends to favour keeping object untouched.
- 2) structural mitigation tends to change objects.

Heavy interventions may improve the safety of buildings but, concomitantly, they may endanger important values that one tries to protect. On the other hand, light interventions may leave the building at risk, in a state of danger also threatening its values. The principle of "minimum intervention" addresses this problem; it looks for a balance. Interventions should be necessary (not too heavy) and sufficient (not too light). If the risk is deemed too high, how much are we ready to change the object now to preserve its values for tomorrow?

Even "invisible" interventions (hidden behind the surface of the construction) have an impact on values. In the process of finding a good balance between changes and preservation, documentation has a key role to play: it helps reducing 'uncertainty'. In a context of trying to find an optimum, it is important to have a clear idea about the objective (some function of values) and to have the best possible data to produce reliable estimate of the risk threatening this objective.

The construction sector also seeks optima. 'Life' and 'investment' are the two main values that structural design tries to protect. Ideally, every step of the construction process is codified accordingly: materials, techniques, workers, design method, etc. This organisation, whose aim is to increase efficiency and safety, allows the various agents to work relatively independently of each other and yet to produce together complex products, satisfying the needs of the society. Engineers like other professionals are trained to fit in this logic.

In the framework of built heritage conservation, complications arise:

Firstly, 'life' and 'investment' are still important, but are not the only values to protect. Secondly, the problem with the modern process described above is often not effective with structures built in an other cultural context. The misunderstandings between the Italian masters of the cathedral of Milan and the French master Jean Mignot at the end of the 14th c. is an early illustration of this observation⁵. To precise the specific context of the object under investigation, all its values need to be identified. The interest placed in Cultural Heritage is often resulting from its rarity or even uniqueness. Time, cultures, technical and artistic skills, physical context have produced a huge diversity of objects. It can be taken as an ethical requirement to recognise that every piece of cultural heritage is potentially different and merit a customised approach. Documentation is a way to start from facts rather than habits; it is a step in the 'humble' process of trying to understand and protect objects for what they are, trying not to transform them in what society superficially sees in them. It can be argued that this task is not strictly possible, our understanding being always conditioned by society. It is actually common for words used in the field of conservation to refer to impossible tasks: "conservation", "reversibility", "authenticity" are all unattainable concepts but useful beacons. Here the concept of "minimum intervention" is again useful. Doing as little as possible may be the best way to protect values which are not yet seen but may become of paramount importance in future.

Models

In the framework of structural conservation, the question of 'uncertainty' is especially critical. The inner parts of the fabric are hidden; the materials and structural elements are heterogeneous, their behaviour imperfectly understood; the construction history is often difficult to trace accurately; imperfections, deformations and cracks are common⁶. But, if we want to provide trustworthy estimates, all the relevant parameters need to be measured. The introduction of concepts like the "distinguishing qualities of the structure" certainly does not facilitate the task; it is a plea for a critical look on assumptions. The data collected is then used in models to give new measures of complex aspects, like 'safety', 'risk', 'values'. Models are always needed to apprehend the infinitely complex reality. They are built in a multidimensional space. They are manageable because they are finite, bounded. They have a finite number of dimensions and they are defined by a finite number of numeric parameters. They need to be finite because brains or machines can only process finite sets of data. They are necessary because we want to understand the past and predict the future. It may help us to fare well. The boundaries of models are important to precise. A line can be defined by 5 numbers in an Euclidean space but, in some circumstances thickness is important (more parameters), sometimes it is colour (higher dimension). Sometimes, a parameter or a dimension important to a stakeholder may be forgotten (birds see colours in 4 dimensions). What is the dimension of the space in which Objects of Built Heritage are living? Can structural engineering questions be completely decoupled from the non technical aspects? Certainly not! The first key decision is to identify the dimension of the space in which structural decisions will be taken and to decide what needs to be measured. Failing to do so is prone to lead to misunderstanding.

Measurements

Measurement is the process of assigning numbers to objects or events following rules⁷. Instruments have rules wired in (take the disto, point it to the object, press the button, read). They are related with both models and object or event. They form the link between the abstract models and the concrete objects.

It is not because numbers are assigned that operations mathematically possible with numbers have a meaning. Lengths or areas can be compared and added but measurements can also just be tags. Tags cannot be compared. It is just possible to see if they are equal and to count them. Measurements can also form an ordered list. It may be possible that value 'a' is higher than value 'b' without being able to precise the ratio between them.

Course of actions and events do change objects. Consequently, they will affect potential future measurements done on the object. Tags will change, some values will grow, others will decrease. Is the new situation better? That is a very difficult question to answer. Is 'historical value' more important than 'aesthetical value'? What is the ratio between the value of the Pantheon and the value of the Colosseum? Is it better to build schools or repair monuments in Afghanistan? Is it a good idea to introduce anchoring in Classical architecture? Or to reinforce vaults with FRP? Those questions will be answered differently by various deciders, in different circumstances. Actually, what deciders are doing, willingly or not, formally or not, is to assign real numbers and weights to every measurement and reach a single, debatable, decision. Some questions are unsettling. Do we want to answer them? Probably not! But society gives an answer to them anyway⁸.

In this context, the aim of documentation and the role of the technicians is arguably to describe a situation, to provide measurements (tags, ordered lists, addable values) that will make an informed 'political' or 'ethical' decision possible. Those measurements will also need to be taken in the proper dimension. The 'socratic' presupposition is that decisions are better when they are informed.

Measuring constructions

Three points define a plane, two points a vertical plane. How many points need to be measured to record a wall? A model will need to be chosen. Architects, historians, archaeologists and engineers will probably see and model it differently. If the model is just a section, an architect may decide to cut the building at the level of a window. For an engineer, it may be more useful to cut it at the level of a buttress or where the wall is most inclined. For structural analysis, materials, deformations (bulges, traces of relative movements, cracks) will often be important to document. They will affect the safety estimates, give clues to the structural history of the structure and record a situation which can be monitored. To produce models documenting the aspects useful to each specialist, it is important to organise collaboration from the very beginning.

Observation *in-situ* is the most straightforward tool to decide what should be the minimum level of complication for the model. It is often sufficient to look at the object from different angles, to touch it, to compare it with neighbouring objects. Control measurements may also be made to confirm that a more sophisticated model is not necessary. As for cultural heritage in general, it is better to work as much as possible on the site, where assumptions can be controlled directly.

Modelling the inner parts of structures is prone to higher uncertainty than modelling their shapes. Destructive samples (to identify materials, structures, resistance, stresses) can only be done in a limited number of points. Assumptions are then made about continuity or behaviour between sample points (interpolation and/or extrapolation rules). Non-destructive techniques can improve the situation but uncertainty is likely to remain high. It is always useful to have a good quantitative idea about expected variations.

Experience and knowledge acquired about similar constructions, built in a similar cultural context is very valuable. The study of ruins and failed structures is especially instructive. They give a direct view of their inner structure and may help understanding their mode of failures. Even if it must be kept in mind that induction is always dangerous.

The need to consider, define and control accuracy is common to all measurement activities. Measurements are never exact. Accuracy of a model is not the same as accuracy of the measurements. If it is unlikely to produce accurate models from inaccurate measurements, it is not at all uncommon to have inaccurate models defined by accurate measurements. Documentation is a two-times process. First, there is a qualitative decision about the model (example: the shape is a cube), then a measurement is made (example: the side of the cube is 20mm). In the example above, if the shape is not a cube, the model will not be accurate, even if the measurement of one of the edge is excellent.

The model should be complex enough to form a good base for the evaluation of the vulnerability of

the structure. The technique and instruments chosen to measure the parameters of the model should be accurate enough to define the model.

Nowadays, automatic and semi-automatic measurement techniques like laser scanners, photogrammetry or monitoring systems are more and more common. They offer many advantages but some of their peculiarities need to be kept in mind.

Like CD recordings, they attempt to produce the "objective" image of a continuous process. But there is no such thing as continuous recordings. Documentation is always a process of discretisation. As it is well known from sampling theory, the highest frequency that can be modelled will depend of the sampling rate. This is true in time and in space. A laser scanner does not measure accurately edges and fine details. Dealing with electric signals, it is customary to pass the data through a low-pass filter before sampling to eliminate non interesting frequencies, avoid aliasing and moiré patterns. For music recordings, that is not a concern. The sampling frequency is chosen high enough to record all audible frequencies. This is not yet practical with laser scanners and photogrammetry. Fortunately, for structural analysis the lower frequencies are usually the most relevant (which is not the case for architecture). In the structural context, another limitation is generally more stringent: most often, these techniques produce incomplete models. Only the parts visible from the station of the camera or the scanner are surveyed. It is in fact quite common in relation to documentation of cultural heritage that it is often necessary or more efficient to use more than one technique to produce an accurate and complete model. The current excitement around laser scanners and the new possibilities that they bring may lead people to forget this fact and the interest of taking time to turn data into knowledge.

Laser scanners in particular are nevertheless very useful tools for structural engineers. They produce a large quantity of data which can be used to model and monitor shape and deformations in 3D. It is probably better to see them as measurements providers than models providers.

Thematic documentation sets

The most common form for the recording of a structure is a set of measured drawings: plans, sections, elevations, details. This set is often directly used by engineers to build models, the idealisations used to evaluate the vulnerability of the real structure. Nowadays, computer models (2D or 3D) are obviously getting more and more common. In what follows, we will nevertheless continue to speak about drawings, even when similar statements can be made for computer models. Furthermore, it may be argued that to print information has still its advantages: it encourages synthesis, it facilitates exchange of information with specialists of other disciplines (which may not have access to the software tools or not familiar with its use), it presents interest for archiving purposes, etc. For structural analysis of historic structures, a good set of measured drawings is particularly important. For long periods of history, design was more a matter of geometry than materials. Often, problems are related to this dimension. This model provides information about the shape of the structure and possibly about its deformations.

It is anyway useful to proceed with the process of documentation and produce thematic sets of drawings presenting other pieces of information useful to structural analysis. In general term, this information can be added on a dedicated set of drawings, on a copy of the shape survey. Thematic sets can for instance document the material used, the hidden reinforcements, the constructions phases, the expected actions on the structure, the cracks, the deformations (monitoring, hypothesis on the way a structure is expected to move and possibly collapse)... Information can often be presented in the form of a coloured maps. If it is not possible or adequate, other graphic presentations can be devised or annotations directly added to the drawings. There is still place for ingenuity to transmit clearly information.

As mentioned in the previous section, what is meaningful depends of the specificity of a situation. Some sets provide data directly necessary to build the mathematical models used to assess vulnerabil-

ity (shapes, materials, construction techniques...). Other sets provide indirect clues about the structural behaviour of a structure. This "circumstantial evidence" may increase confidence in a diagnostic. The use of thematic sets of drawings presents important advantages:

- *It requires to be explicit and exhaustive.* Whichever technique of assessment is chosen, assumptions will always have to be made about key characteristics of the structure (the density of the material used for instance). The requirement to have every single part of the construction qualified results in a clear and manifest presentation of assumptions. Willingly or not, texts can be more ambiguous, especially about extents or limits. The process may be technically and/or conceptually difficult. Samples may for instance be taken only in a few limited places. Extrapolations are uncertain. But the results of sampling is anyway going to be used to qualify a context larger than its strict domain of validity. Putting this information on plans just make this step conspicuous. The degree of certainty in the information provided can also be documented. Texts should precise the methodology.

- *It requires to be explicit about categories and their definition.*

How many materials are present? What type of movement is associated to a given crack? Photographs show a situation in all its complexity, as it appears to first-time visitors. Graphical representations are the result of an interpretation of observations, of an analytical process implying time, expertise and abstraction. To classify requires to fix a limit between what is meaningful and what is meaningless. Again, this is a process open to critics but, whichever technique of assessment is chosen, abstractions or simplifications are made and to have them stated in legends, atlas of type (see ICOMOS stone committee document⁹) or reasoned lists will facilitate appraisal of the quality of the analysis.

- *It presents a synthetic view on aspects most often perceived only locally.* To see a crack in a narrow spiral staircase for instance probably provides less insight than to see it in a broader context, in a section where all cracks are documented and to be able to compare this section with a similar drawing presenting the construction phases or the deformations.

Synthetic presentations also enhance clarity and facilitate communication.

- *It encourages collaboration between specialists involved in the conservation process.* To produce thematic maps imply various types of actions: to measure, to draw, to identify, to interpret. Those actions are often better lead by or taken in collaboration with specialists. To document the use of materials may for instance benefit from a collaboration between a geologist, an architect and an engineer. The requirement to work on a common set of drawings may facilitate a full and effective transmission of information. Reports follow the logic of a discipline, they are often difficult to understand by specialists from other disciplines. There is nevertheless a need to share information. Thematic drawings can serve as an interface.

- *It enhances the transparency of the appraisal process.* It is an ethical requirement of conservation to make every step in the decision process as explicit and understandable as possible.

It is clear from the above discussion that thematic sets present a subjective view on the situation of the structure. Those views are the result of interpretations which can always be criticised. They may be wrong or incomplete. To some extent, their quality can be judged from self-consistency considerations or comparing them with other subjective interpretations. But it is also important to have the possibility to compare it with more "objective" data.

Photographs have a special interest in that respect. It is particularly useful to have a complete, systematic and neutral photographic documentation of the whole structure, not limited to particular details deemed meaningful by a given specialist. It should be accessible to all the actors involved in the conservation process. To become an effective tool, the set should be easily browsable. Photographs relevant to a specific problem should be accessible quickly. An electronic form facilitates those requirements.

Specialist reports will also separate clearly data and interpretation.

As already discussed, data uncertainty is usually important. Even seemingly objective analysis are

based on subjective assumptions. Some features may not be measurable. Some may not be accurately measurable. Interpolation and extrapolation of measures are often critical.

From the point of view of the structural engineer, the main purpose of documentation is to provide the data necessary to evaluate how the vulnerability of the structure affects risk on its values and, possibly, design strategies to mitigate it. The structure has to be characterised as well as possible. Ideally, engineers need to know how it is built, with which materials, having which characteristics (density, resistance, ...). They also need to know about its defects, about the history of its construction and of its misadventures and about the evolution of the actions on the structure. And, as discussed above, the values potentially affected by structural events have to be identified and 'measured'. Most of the data will be conjectural.

A good documentation should make those limits explicit.

If there is a good -and soundly based- confidence that the values associated with a structure are safe, documentation is not required for conservation purpose. It is when the necessity of an intervention is suspected that documentation should be produced or improved. Interventions may indeed affect the values (heritage values and associated costs). A progressive approach is always beneficial. The aim is to protect values as well as possible. The depth of analysis may change. If better data can produce confidence that the structure is safe, there is no need to enquire further. If better data demonstrates the necessity of an intervention, it is likely to be beneficial for heritage values to continue the process of documentation and analysis in order to reduce uncertainty in search of the minimum intervention. In reality, the limit will be fixed by other considerations. How much deciders are ready to pay in preliminary studies to improve the chance of a marginal gain (lighter intervention, better protection of heritage values)? What is the attitude of deciders in front of risk? Is it better to be sure at 99% to keep 75% of the values (in the following 100 years) or to be sure at 75% to keep 99% of the values.

Notes

- ¹ The International Committee for Documentation of Cultural Heritage (CIPA) is one of the international committees of ICOMOS (International Council on Monuments and Sites) and it was established in collaboration with ISPRS (International Society of Photogrammetry and Remote Sensing). <http://cipa.icomos.org/> ICOMOS (1996). *Principles for the recording of monuments, groups of buildings and sites*.
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