Reinforced Concrete Condition Assessment in Architectural Heritage.

The Lion Chambers (Glasgow, UK) and the Theatre E. Duni (Matera, Italy)

Faculty of Engineering
DEPARTMENT OF ARCHITECTURE, PLANNING
AND TRANSPORT INFRASTRUCTURES

**School of the Built and
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The research undertaken in this study has been initiated following the agreement between Glasgow Caledonian University (GCU) and University of Basilicata (USB) to establish research collaboration. The aim of the collaboration is to use the expertise available at both institutions on a range of research projects in the field of sustainable refurbishment of buildings to assist in decision making for preservation and revitalisation of architectural heritage.

GCU's researchers have been undertaking research in collaboration with Historic Scotland and with researchers involved in the UK and EU funded projects. GCU is leading CIC (Construction Improvement Club) Start Online (www.cicstart.org), a joint project of seven Scottish universities whose aim is to support collaboration between academia and construction sector to develop and test innovations for sustainable building design, construction and refurbishment. CIC Start Online activities are disseminated online through interactive webinars, video recordings and online conferences.

The researchers at USB carry out research in restoration of built heritage, sustainability of building process, restoration and rehabilitation of historic centres, and refurbishment of the monuments. The research group collaborates with the *Soprintendenza per i Beni Architettonici e per il Paesaggio della Basilicata* and the *Istituto per i Beni Archeologici e Monumentali* IBAM/CNR (Potenza) and undertakes test campaigns to learn about technical and environmental qualities of buildings, and to evaluate their environmental impact.

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Preface

by A. Restucci, Chancellor of I.U.A. of Venice, Italy

This book emerges from the already ripe need to compare experiences in the field of architecture and restoration of the built heritage in Europe. The relationship and the exchange of experience between two European universities, the University of Basilicata and Glasgow Caledonian University, have identified a scientific route to restoration that can become a reference point for subsequent research.

The choice of the buildings was not accidental as the Lion Chambers in Glasgow (1904-07) and the Duni Theatre in Matera (1950) do not represent contemporary cultural tendencies but rather serve as testimonials of local platforms for future interventions, fascinating in their intention to carry out projects recognizable within the urban context as images that come from a culture that chooses technology as an instrument for identifying an "object", but does not seem to wish to recognize the urban reality in which it is located. This is the case in Glasgow just as in Matera, and is poignantly observed by Antonella Guida in this book in which she highlights the architects' wish to project their own emotions through futuristic images.

James Salmon Jr and John Gaff Gillespie, the designers of the Lion Chambers in Glasgow and pioneers in the use of reinforced concrete in non-industrial buildings in Europe, bravely experimented with construction materials, techniques and services, and playfully, but functionally designed the building elevations, as presented by Branka Dimitrijevic in this study. Their design approaches signalled the start of an exploration in design and building with reinforced concrete. Ettore Stella, with his Duni Theatre in Matera opens oblique paths for the journey of an architecture unwilling to return to typological schemes, but wishing to present itself as a concerned point of interrogation in which form aspires to reunite with technological innovation. The two buildings, which constantly seem to confront an idea of unity between the city and the architectural object, are brought together by their desire to avoid the issue of design meaning, as Guida underlines in her critical reflections.

The architectural culture perceived in Ettore Stella's project in Matera had to cope with multiple enemies, even with a battle to engage others with itself, with local traditions, with the bond that links the design to a subversion of established conventions. For Ettore Stella, form represents a restraint to the vibrant play with which he shaped the surfaces of his theatre, and his aversion towards the limits of all governing rules became "imaginative freedom". In Matera, this experiment in fluidity of space and ramification of structure opposes, as in Glasgow, the contemplation of the urban context.

Next to the regionalism, the humanistic romanticism, next to the heavy burden that filters from everything surrounding Stella's building (a perhaps also the one in Glasgow), its emergence signalled a new idea of design. With the Duni Theatre in Matera, Stella gives life to a unique attempt to force architectural logic, displaying a real battle between material and structure, moulded by the most inspired of contortions. An ensemble of spaces is brought to light, and perceived as a challenge to contemporary design. It is a place that invites participation which dislikes geometry when conceived as a coercion.

This study by Antonella Guida and Branka Dimitrijevic identifies a whole range of variations regarding informal themes: a language composed of distortion, membranes, intertwined paths, material and invention. All this makes Stella's journey different from those of other important designers such as Ludovico Quaroni, Giancarlo De Carlo, Carlo Aymonino who also left on Matera the mark of this Italian architecture focused on the quality of the object and its history.

This is a work that tackles, along with historical considerations, a series of questions related to the problem of restoration of the structures studied in Glasgow and Matera. The tests for assessing the condition of reinforced concrete structures in both buildings, undertaken by Antonello Pagliuca, will contribute to the knowledge required to plan their restoration and maintenance. This problem can spark collaboration between institutions which consider research and sustainability as topics for the future; this book seeks to offer strategic reflections that today's "building" cannot neglect.

In the last decades, the architectural heritage of the modern movement seems to be more at risk than during any other period. This built inheritance embodies the dynamic spirit of the industrial age. At the end of the 1980s, many modern masterpieces had already been demolished or changed beyond recognition. This was mainly due to the fact that many were not considered to be elements of heritage, that their original functions have substantially changed and that their technological innovations have not always endured long-term stresses. Recognising this threat, The Twentieth Century Society was founded as the Thirties Society in 1979 in the United Kingdom. "The Society's prime objectives are conservation, to protect the buildings and design that characterise the Twentieth Century in Britain, and education, to extend our knowledge and appreciation of them, whether iconic buildings like the Royal Festival Hall or everyday artifacts like the red telephone box"[1].

Sustainable preservation and reuse of architectural heritage contribute to the reduction of carbon emissions and more sustainable development of built environment. If the targets for reduction of carbon emissions are to be achieved, sustainable refurbishment of existing buildings must be undertaken. In Italy, along with the Ministry for Cultural Heritage and Activities, preservation institutions and research centres, the cultural association DO.CO.MO.MO operates since 1995. Its objective is to document and conserve modern buildings and urban areas, to contribute to the evaluation of modern architecture, and to promote its preservation and research on methodologies and appropriate intervention criteria[2].

A thorough research of built heritage enables understanding of the evolution of design philosophies and underlying cultural meanings and messages, artistic and functional qualities, and engineering achievements. A detailed knowledge of building materials, construction techniques, environmental services (e.g. heating, ventilation, water etc.), external impacts (e.g. weather, pollution, flora and fauna) and internal impacts of use or disuse assist in identifying the problems affecting buildings and defining a methodological approach for sustainable interventions. Sustainable preservation and the reuse of architectural heritage contribute to the reduction of carbon emissions and to a more sustainable development of the built environment. If the targets for reduction of carbon emissions are to be achieved, sustainable refurbishment of existing buildings must be undertaken.

The aim of the research collaboration between Glasgow Caledonian University and the University of Basilicata is to exchange ideas relating to conservation technology and history; to foster interest in the ideas and heritage of the Modern Movement, and to provide documentation in support of conservation of valuable buildings, sites and neighbourhoods of the Modern Movement.

The research objective is to provide new qualitative

[1] The Twentieth Century Society: About the Society, at http://www.c20society.org.uk, accessed on 20/03/2011.
[2] DO.CO.MO.MO. Italia. About it, at http://www.docomomoitalia.it, accessed on 14/04/2011.

information on the strength of reinforced concrete structures of two prominent examples of modern architecture by using innovative, non-invasive testing techniques. The first one is Lion Chambers in Glasgow (Scotland, United Kingdom) designed by the architects Salmon, Son and Gillespie and completed in 1907. The second one is Duni Theatre in Matera (Southern Italy), designed by the architect Ettore Stella and completed in 1949.
The Lion Chambers was the second example of the use of François Hennebique's reinforced concrete system in a building in Glasgow and one of the earliest in Britain. The confluence of the local architectural styles (vernacular and academic) and the emerging aesthetic of reinforced concrete is explored to outline the context that influenced the building design which led to the direction of the Modern Movement, away from Art Nouveau whose Scottish interpretation gained international recognition in the works of Charles Rennie Mackintosh, a good friend of James Salmon Jr. Aesthetics of the Modern Movement sought to express the physical characteristics of new building materials and to explore how they can be used to develop innovative structures and forms. The Austrian architect Otto Wagner was the first to take a leap from past styles (vernacular or academic) and structural or decorative interpretations of the natural world towards the minimalism of structural needs and exposed materials such as reinforced concrete, different metals and glass in the design of the interior of the Post Office Savings Bank (1904-12) in Vienna.

The Theatre Egidio Romualdo Duni in Matera is an excellent example of early Modern Movement architecture in Italy. The designs of the architect Ettore Stella were influenced by the work of architects such as Giuseppe Terragni (1904-1943), Walter Adolph Gropius (1883-1969), Richard Josef Neutra (1892-1970) and Frank Lloyd Wright (1867-1959). In the years immediately after the Second World War, Stella was a proponent of the revision of the methodology for evaluating the architectural heritage that would include a successful integration of technological innovations. He demonstrated how the inclusion of a building in an urban context is more successful if it is not forced to 'mimic' its surroundings even when including architectural elements that directly express manufacturing processes (e.g. through the use of reinforced concrete, high quality arts and crafts etc.).
The research methodology includes (a) the context in which the buildings were designed, (b) their history, (c) building technologies used, (d) non-invasive testing of the reinforced concrete structures, (e) the analysis of the test results and (f) the conclusions.
Testing methods could be "distructive", as they require a local removal of material, or "non-distructive", i.e. they do not affect the structure. A sclerometer test, an ultrasonic test and their combined use, called SonReb (SONic+REBound), are "non-destructive" tests on reinforced concrete. The combined tests are a very useful method for assessing the concrete strength and to reduce the possibility of errors that can happen if the tests are not combined, as it has been noticed that the humidity content of a structural element can influence the sclerometer index and the ultrasound speed[3]. The combined method requires shorter time to obtain the results.
The research outcomes are of interest to the architects and engineers operating in the construction sector, researchers in history of architecture and construction, as well as officials of the institutions responsible for conservation of built heritage.

[3] Masi A., *"La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive"*, Il Giornale delle Prove non Distruttive Monitoraggio Diagnostica, n. 1, 2005, p. 6.

1.1 **Early applications of reinforced concrete in *“Modern Architecture”*: Europe and UK**

The philosophy of Modern Architecture can be traced back to the question raised by Claude Perrault (1613-1688) on the validity of the Vitruvian proportions refined through Classical theory.[1] Perrault was a French architect and physicist who translated ‘Ten Books on Architecture’, written by Marcus Vitruvius Pollio (c. 80-70 BC – c. 15 AC), and used a Classical order for the design of the Colonnade and east front of the Louvre (1667-1670) in Paris.[2] Perrault’s knowledge of Classical and other historical architectural styles enabled him to understand the limitations in their application to utilitarian and other buildings whose function did not require monumental architectural orders or decoration. He proposed two different design approaches – one that has a normative role of standardisation (of historical styles in architecture) and an alternative one that expresses functions as may be required by particular circumstances or character.[3] The former was taught from 1671 at the Académie d’architecture, which was merged with the Académie des Beaux-Arts in 1795, and the latter was developed at the École des Ponts et Chaussées from 1747.[4]
This divide in the teaching of building widened with the emergence of new building materials and construction technologies in the 19th century. Heavy building proportions and intricate decorative elements of historical architectural styles were suitable for stone, but not for iron, steel, reinforced concrete and large glass surfaces whose load bearing properties, textures, colours, physical characteristics and manufacturing processes required different design approaches. However, Jean-Nicolas-Louis Durand (1760-1834) attempted to provide a system for using Classical forms for a range of new buildings in his *Précis des leçons données à l’Ecole Polytechnique* (1802-09).[5]
Knowledge on the behaviour of new building materials in different climates and weather conditions, their durability or thermal properties, was not readily available. The use of new building materials and techniques in the 19th century instigated learning through experiments and research on physical properties and behaviour of new building materials within composite building elements, in contact with other materials and within the whole structure. At the same time, the aesthetics of iron, concrete and glass were explored. A departure from historical architectural styles led to a freedom in the design of structural elements, building envelopes, layouts and forms. These experiments in building

[1] Frampton, K., *Modern Architecture: A Critical History*, Thames and Hudson, London, 1992, p. 14.
[2] Bazin, G., *Baroque and Rococo*, Thames and Hudson, London, 1993, p. 121.
[3] Frampton, op. cit., p. 14.
[4] Ibidem, p. 12.
[5] Ibidem, p. 30.

engineering and design laid the foundations for Modern Architecture of the 20th century.
Since its development in the 19th century, reinforced concrete has been used for the construction of civil engineering projects and different building types. It is a structural element composed of concrete and iron or steel bars. Cement, aggregates and water are basic components for concrete mixture.[6] The use of monolithic concrete (without iron bars) in Roman architecture and civil engineering structures enabled the construction of wider spans, but the concrete surface was covered with stone or brick. During the reign of Louis XVI (1754-1793), stuccoed rubble was increasingly used with a finish that imitated masonry.[7] The use of timber formwork for moulding mud walls of French rural buildings and the publication on *Experimental Researches into building limes, concretes and ordinary mortar* (1818) by Louis Vicat (1786-1861) inspired the architect Françios-Martin Lebrun (1799-1849)[8] to build a house at Marssac (1832), near Albi in France, that has walls, floors, external staircase and vaults between the floors of compressed concrete.[9]
The use of wrought-iron in building began with masonry reinforcements in French medieval cathedrals, and later in Perrault's east facade of the Louvre, Jacques-Germain Soufflot's (1713-1780) portico of St-Genevieve (1772, Panthéon), Victor Louis' (1731-1800) roof for the Théâtre Français (1786) and the theatre in the Palais-Royal (1790).[10] In Britain, cast-iron beams were used for the first time in Salford Mill, Manchester (1801), designed by English manufacturer Matthew Boulton (1728-1809) and Scottish engineer James Watt (1736-1819).[11] The first building with cast and wrought-iron frames was a four-storey boat store in the Naval Dockyard at Sheerness (1860), designed by Colonel G. T. Green (1807-1896).[12]
The first glass barrel vault on cast-iron frames was Pierre Fontaine's (1762-1853) Galerie d'Orléans, built in the Palais Royal in 1829.[13]
Prefabrication of cast-iron systems enabled fast assembly on a building site and transportation of structural elements to locations across the world. Joseph Paxton's (1803-1865) Crystal Palace (1851) in London, built in four months, demonstrated the speed of the construction process and the emerging aesthetics of iron and glass buildings.[14]
Experiments in combining concrete and iron started in the first half of the 19th century. John Claudius Loudon (1783-1843), a Scottish landscape architect, recommended in his *Encyclopedia of Cottage, Farm and Villa Architecture* (1834) a system of fireproof flooring consisting of a latticework of iron rods embedded in cement.[15] A structural system that combines mass

[6] For information on history of concrete see Newby, F., The innovative uses of concrete by engineers and architects, in Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal*, Thomas Telford Publishing, London, 2001, p.11-44.
[7] Collins, P., *Concrete: the vision of new architecture*, McGill-Queen's Press, 2004, p. 19.
[8] Rico, R. François-Martin Lebrun (1799-1849) Architecte et précurseur du béton, *Bulletin de la Société archéologique de Tarn-et-Garonne*, 2004, vol. 129, pp. 107-119.
[9] Collins, P., op. cit., p. 25.
[10] Frampton, op. cit., p. 30.
[11] Ibidem, p. 32.
[12] Millias, M. *Building Structures: from concept to design*, Spon Press, Oxon, 1997, p. 296.
[13] Frampton, op. cit., p. 33.
[14] Ibidem.
[15] Collins, P., op. cit., p. 29.

concrete and inverted T-section cast iron beams was developed by Henry Hawkes Fox and James Barrett in 1844.[16] W.B. Wilkinson, a Newcastle plasterer, took out an English patent in 1854 for embedding in floors or beams of concrete (either arched or flat) a network of flat iron bars.[17] Françios Coignet (1814-1888) commissioned the architect Théodore Lachèz to design a concrete house in French Neo-Classical style with iron beams in its flat roof at St. Denis in Paris in 1853, then took out a patent for monolithic concrete, exhibited at the Universal exhibition of 1855, and boldly declared that the reign of stone in building had come to an end and that cement, concrete and iron were destined to replace it.[18] In 1861, Coignet formed the *Société Centrale des Bétons Agglomérés* and continued experimenting with monolithic concrete on different building types, including a six-storey apartment block in Paris in 1867 designed in the style of Parisian housing architecture.[19] The engineer Jean-Charles Adolphe Alphand (1817-1891) designed Parc des Buttes Chaumont in the 19th arrondissement, completed at the opening of the Exposition Universelle in 1867, which showcased advances in industrial materials and innovative building practices and technologies, demonstrating their aesthetic merits.[20] Concrete was used for the lining of the lakebed and the hard-edged curb of the lake in the park. *Stuc ciment*, a relatively loose or wet mix of cement, sand and lime, was artistically applied over a foundation of masonry, rock or concrete. Reinforced concrete was used for architectural features, stairs, handrails and the massive retaining walls lining the railroad embankment next to the park.[21]

At the 1855 exhibition, Joseph Tall, an English building contractor who developed demountable and reusable shuttering, won a gold medal and was commissioned to build workmen's dwellings in the Boulevard Daumesnil in Paris.[22] Sephard and Newton are also mentioned as contractors of these houses.[23] Charles Drake, who had been employed by Tall as his manager, developed a system with metal instead of timber up-rights, and built cottages, villas, churches and halls imitating historic architectural styles from 1868.[24] Architect and builder W.H. Lascelles (1832-1885) patented a reinforced pre-cast slab construction in 1875 and collaborated with the architect Richard Norman Shaw (1831-1912) on the design of cottage buildings.[25] Engineer Philip Brannon developed patents for monolithic concrete reinforced with iron rods in 1871 and 1874 and built a few large houses, but also contributed to public anxiety towards concrete when his buildings in Islington, London, collapsed owing to faulty construction.[26] As the reinforced concrete was

[16] Ibidem

[17] Hamilton, S. B, *A Note on the History of Reinforced Concrete in Buildings*, National Building Studies, Special Report No. 24, Department of Scientific and Industrial Research, Building Research Station, Her Majesty's Stationary Office, London, 1956, p. 2.

[18] Ibidem, p. 28, 29.

[19] Ibidem, p. 34.

[20] Komara, A., Concrete and the Engineered Picturesque: The Parc des Buttes Chaumont (Paris, 1867), *Journal of Architectural Education*, 2004, Vol. 58, Pt. 1, p.5.

[21] Ibidem, p. 9.

[22] Collins, P., op. cit., p. 41.

[23] Dumont, M.J., *Le Logement social à Paris 1850-1930: les habitations à bon marché*, Pierre Mardaga Editeur, Liège, 1991, p. 15.

[24] Ibidem, p. 42.

[25] Ibidem, p. 43.

[26] Ibidem, p. 43, 44.

considered fireproof, it was used in construction of fireproof walls in several theatres, e.g. in Tivoli Theatre in Aberdeen (1872), designed by Charles Phipps (1835-1897).[27] In the Royal English Opera House (1889, now the Palace Theatre), designed by Thomas Edward Collcutt (1840-1924), a monolithic concrete structure was used for walls, seating rumps, balcony fronts and all the roofs. Steel and concrete were used for the floors, ceilings, staircases and landings. The nine meters deep cellar was made waterproof by successive layers of concrete and asphalt.[28] However, the fireproof properties of reinforced concrete were disputed by Professor John Goodman in *Building News* in 1891 because 'iron expands rapidly under the influence of heat, and consequently disturbs and breaks the rigid concrete.'[29] By 1892, British architects and engineers had almost completely lost interest in further development of reinforced concrete on a larger scale, and the lead was taken by the French. One of the reasons for the hesitation in using reinforced concrete was a lack of engineering knowledge in the education of some architects such as the architect William Lethaby (1857-1931), whose competition project for a reinforced concrete Liverpool Cathedral (1902) was not successful, and who wrote:

"It is absurd, for instance, that the writer should have been allowed to study cathedrals from Kirkwall to Rome and from Quimper to Constantinople; it would be far better to have the equivalent knowledge of steel and concrete construction. … If I were again learning to be a modern architect, I'd exchange taste and design and all that stuff and learn engineering, with plenty of mathematics and hard building experience. Hardness, facts, experiment - that should be architecture, not taste."[30]

However, the interest in using reinforced concrete continued in Liverpool; the flats in Eldon Street were built of precast concrete in 1905; and in 1909, the Royal Liver Building in Liverpool, designed by Walter Aubrey Thomas (1859-1934), was built with reinfoirced concrete frames (Hennebique's system)[31] behind its monumental, 90m high facades whose design relied on historical architectural forms.[32]

François Hennebique (1842-1921) first used pre-cast concrete beams containing cylindrical iron rods in the floors of a house built in 1879.[33] He continued research and experiments on columns, beams and slabs, and then took out patents for a new reinforced concrete system in 1892, establishing himself as a consultant engineer to ensure quality control through affiliated building contractors.[34] Hennebique employed and trained young engineers, and publicised his system through manifestos, annual congresses in Paris from 1897 and a monthly magazine *Le Béton Armé* from June 1898.[35] His

[27] Ibidem, p. 52
[28] Ibidem, p. 54.
[29] Quoted here from Collins, P., op. cit., p. 54.
[30] Rubens, G., William Lethaby's Buildings, in Service, A. (ed.) *Edwardian Architecture and its Origins*, London, 1975, p. 141.
[31] Newby, F., The innovative uses of concrete by engineers and architects, in Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal*, Thomas Telford Publishing, London, 2001, p. 74.
[32] Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal*, Thomas Telford Publishing, London, 2001, p.1.
[33] Collins, P., op. cit., p. 64.
[34] Ibidem, p. 65.
[35] Ibidem, p. 66, 67.

first reinforced concrete buildings were spinning mills in France whose exposed frames rhythmically divided facades and enabled the use of large window surfaces. When the business expanded, Hennebique commissioned the architect Edouard Arnaud (1864-1943) to design the company headquarters and the flats above them in rue Danton, Paris, in 1898.

Hennebique demonstrated his openness to the enquiry of architectural design of reinforced concrete by inviting Pascal Forthuny (1872-1962), a well-known architectural critic, to comment on the design of the company headquarters. Forthuny's comments were published in the firm's magazine in May 1901, thus spreading the message that could have reached everyone interested in designing with reinforced concrete:

'… Reinforced concrete is a new material, and has no links with the systems of construction that preceded it; it must thus necessarily draw from within itself its exterior aspects, which must be clearly differentiated from familiar motifs in wood, marble or stone.'[36]

Hennebique's system was used in the construction of theatres in Morges and Berne (Switzerland), Münich (Germany) and for the Théâtre des Champs-Elysées in Paris, designed by Auguste Perret (1874-1954) in 1911.[37] By 1902, Hennebique had more than fifteen hundred contracts a year with licensed contractors in nearly every European country, and by 1917 he had completed 17,692 building contracts and a similar number of engineering works.[38] Hennebique participated in drawing up the official regulations on the use of reinforced concrete, published in 1906.[39] His important contribution was in proving that reinforced concrete is a construction material that can be used safely and in initiating its use across Europe.

The 1900 Exhibition in Paris, for which many buildings were designed in reinforced concrete, is considered as a principal event that influenced the adoption of this system in other European countries.[40] In 1903, the architect Auguste Perret (1874-1954) used a concrete frame for a 10-storey block of flats in 25 Rue Franklin in Paris.[41] Over fifty different reinforced concrete systems were developed by 1904.[42] However, François Hennebique's system expanded across Europe due to his organisation of the business which controlled both design and construction.[43] Louis Gustave Mouchel became Hennebique's agent in Britain from 1897-98.[44]

The use of reinforced concrete structures started in Glasgow in the last decade of the 19th century. William James Anderson (1863-1900), who was appointed as Dean of Architecture at the School of Art in 1894, designed Orient House at 16 McPhater Street in Cowcaddens (1892-95).[45] Its Italian Renaissance facades with

[36] Ibidem, p. 70.
[37] Ibidem, p. 71.
[38] Ibidem, p. 72.
[39] Ibidem, p. 75.
[40] Ibidem, p. 72.
[41] Newby, F., The innovative uses of concrete by engineers and architects, in Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal*, Thomas Telford Publishing, London, 2001, p. 23.
[42] Marsh, C.F., *Reinforced Concrete*, London, 1904. As quoted in Cusack, P., Architects and the reinforced concrete specialists in Britain 1905-08, *Architectural History*, 1986, Vol. 29, p. 193.
[43] Cusack, P., Architects and the reinforced concrete specialists in Britain 1905-08, *Architectural History*, 1986, Vol. 29, p. 183.
[44] Op. cit.
[45] Extract from Statutory List, Glasgow City Council, HB number 32754, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011

stucco finish do not indicate that the building structure was in fact made of steel frames with concrete floors, ceilings and a flat roof finished with asphalt.[46] His second project with steel framing and reinforced concrete was Neptune House, 638-646 Govan Road (1898-9). Unfortunately, the building's fifth floor collapsed causing the death of five workmen and, ultimately, his death through stress.[47]

Archibald Leitch (1865-1939), engineer with Brand and Lithgow Architects, used the Hennebique reinforced concrete system in the construction of the Sentinel Works (1903-04) at 61 Jessie Street. The industrial, four-storey building has concrete panel walls and large metal-framed windows. Behind its top Classical cornice is a flat roof. The interior is free of columns as the load is entirely carried by the reinforced concrete frames.[48]

An article published in a professional journal in 1907, along with the article on Lion Chambers, informed on the development of knowledge on innovative reinforced concrete structures in Great Britain at that time.[49] It referred to the book *Reinforced Concrete* (1904), considered by the article author to rank as a standard book on reinforced concrete in the English language. This was a translation of *Le Béton Armé* by Paul Christoph who was engineer to the Belgian Government Department of Ponts et Chausées. It was noted that, along with the translation, Charles F. Marsh added a good deal of original investigation in the way of doing calculations for design, together with descriptions of special systems, English and American.[50] The author praised the most recent extended edition co-authored by Scottish architect and engineer William Dunn (1859-1934)[51]. Approximately twenty reinforced concrete buildings were completed or begun in Great Britain by 1904, the year when Salmon, Son and Gillespie decided to use reinforced a concrete structure for Lion Chambers.[52] The building has been recorded in the history of architecture as probably the only non-industrial building constructed before 1910 which did not deliberately disguise its[53] structure.[54]

1.2 T**he search for new aesthetics in architecture in Scotland at the turn of the 20th century**

Scotland's architecture during the 19th century offered a spectrum of historic architectural styles: Gothic revival on churches, neo-Greek and other classical forms on public buildings with the influence of the French Beaux Arts from around 1870, academic baronial (with French or Tudor or Jacobean influences) on the

[46] Blaikie, G. Victorian Glasgow. Commercial Buildings. At http://www.scotcities.com, accessed on 25/03/2011.
[47] Nisbet, G. Glasgow – City of Sculpture, William James Anderson. http://www.glasgowsculpture.com, accessed on 25/03/2011.
[48] Extract from Statutory List, Glasgow City Council, HB number 33693, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011.
[49] Anonymous. Views and Reviews. Reinforced Concrete. *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly)*, 30 January 1907
[50] Ibidem.
[51] Dictionary of Scottish Architects, William Dunn, http://www.scottisharchitects.org.uk, accessed on 24/04/2011. A more detailed overview of the development of knowledge on reinforced concrete in 19th and 20th centuries is available in Hamilton, S. B, *A Note on the History of Reinforced Concrete in Buildings*, National Building Studies, Special Report No. 24, Department of Scientific and Industrial Research, Building Research Station, Her Majesty's Stationary Office, London, 1956.
[52] Cusack, P., Lion Chambers: a Glasgow experiment, *Architectural History,* 1985, vol. 28, pp. 198.
[53] Newby, F., The innovative uses of concrete by engineers and architects, in Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal*, Thomas Telford Publishing, London, 2001, p. 24.
[54] Collins, P., op. cit., p. 82.

country houses, and some baronial vernacular in urban architecture. The industrial revolution in Western Europe during the 19th century created wealth that was re-invested in new industrial buildings, housing, offices and public buildings. Scotland, and particularly Glasgow, contributed to the industrial growth through engineering innovations, shipbuilding and commercial activities on the river Clyde, and a range of manufacturing businesses. From 1890 to around 1910 Glasgow reached the pinnacle of industrial development and wealth. Between 1900 and 1913, the value of exports from the city increased from £18 m to £33 m.[55] Goods and people arrived either through its large harbour or through the Central Station (1879), fronted with a huge Victorian building, designed by the architect Sir Robert Rowand Anderson (1834-1921)[56]. Glasgow marked its prosperity by building the City Chambers (1890), another grand building with opulent and high quality interior finishes, designed by William Young (1843-1900)[57]. The city had strong business links with the USA and Europe that enabled the flow of new technological knowledge.

Judging by the amount, range and quality of buildings of late Victorian Glasgow, it was a good place for a young architect as Glasgow's institutions, businesses and developers invested in architecture.[58] The contemporary experiments in architectural design in Glasgow have produced a range of buildings whose designs do not completely fit into any historical style, but represent a free combination of compositions, forms and decorative elements from different styles. These experiments became known as 'Glasgow Free Style'.[59] Freedom of design was also expressed in different approaches to the composition of building facades and their finishes, an example being the School of Art, designed by Charles Rennie Mackintosh (1868-1928) in Art Nouveau style that included elements of Scottish architectural tradition.

The Glasgow Free Style's search for new forms in architecture, as in other similar movements in Europe and the USA at that time, was a reaction to more than a century of architectural historicism. As interpretations of historical architectural styles had been repeated on architects' drawing boards throughout the 19th century, the German architect Heinrich Hübsch entitled his book with the question that symbolised the era "In welchem Style sollen wir bauen?"(In what style should we build?).[60] In Glasgow, architects who longed for the artistic excitement of creating new architecture were influenced by the tradition of the French Beaux-Arts, the English Aesthetic movement, the refinement and revival of Scottish traditions, both academic and vernacular, and the Arts and Crafts movement from the 1890s.[61]

The image of Glasgow's city centre was changing; as the price of land was going up, so were the buildings, sometimes built on very small plots. New buildings were taller and often built of red stone instead of the earlier preferred pale-yellow or grey stone. The need to build faster and higher led to experimenting with new structural materials such as cast-iron, steel and

[55] Cochrane, H., *The Glasgow – the first 800 years*, Glasgow, 1975, p.54
[56] Williamson, E., Riches, A. and Higgs, M., Glasgow. Penguin Books, New Haven and London, 1990. p. 210.
[57] Ibidem, p. 160.
[58] Walker, D. The Glasgow Years, in Kaplan, W. (ed) *Charles Rennie Mackintosh*, Glasgow Museums and Abbeville Press Publishers, New York-London-Paris, 1996, p. 115.
[59] Gomme, A. and Walker, D., *Architecture of Glasgow*, Lund Humphries, London, 1987, p. 257.
[60] Pevsner, N., *Some Architectural Writers of the Nineteenth Century. Hübsch and the Rundbogenstil*, Oxford, 1972, 62-75.
[61] Walker, D., 1996, p.116.

reinforced concrete. As the city's wealth grew in great part from industrial engineering, there was no fear of applying new technologies in building. Glasgow architects John Baird (1798-1859) and James Thomson (1835-1905), and the engineer Robert McConnell, had been the first in Britain to experiment with cast-iron facades for commercial buildings.[62] Baird's earliest use of cast-iron was for the roof trusses in the Argyll Arcade, 28-32 Buchanan Street - 1827. Baird's and Thomson's Italianate, Iron Building at 36 Jamaica Street, built in 1856-7, was among first buildings whose street facade was almost completely made of glass panels placed between panelled cast-iron columns.[63]
Some tall buildings on small plots were built in Glasgow's city centre around or at the same time as the Lion Chambers. James Salmon Jr designed one of them, the 'Hat-rack' (1902) at 144 St Vincent Street. As the architects were developing new design approaches for tall buildings, a brief overview of a few such buildings in Glasgow provides a background against which the unique design of the Lion Chambers stands out.

Plate 1.1: 179 Buchanan Street

179 Buchanan Street, former Athenaeum Theatre, 1891-3, designed by John James Burnet[64]

The building design (Plate 1.1)[65] shows confidence in creating an asymmetrical facade, in using historical architectural details, in combining different shapes and sizes of windows and even placing them at slightly removed levels on the facade of the stair tower. The master behind the balanced proportions and historical detailing, who was not afraid to explore innovative solutions, was the architect John James Burnet (1857-1938), a son of the architect John Burnet Senior (1814-1901). His partner in the practice was John Archibald Campbell (1859-1909). The asymmetrical composition of the facade and the variations in size, shape and position of windows ought to have been noticed by the architects of the Lion Chambers. Burnet's architectural skills, acquired at the École des Beaux Arts in Paris[66], and his easy adoption of new technologies and design solutions had delivered an architectural

[62] Ibidem.
[63] Extract from Statutory List, Glasgow City Council, HB number 33065, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011.
[64] Extract from Statutory List, Glasgow City Council, HB number 33004, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[65] http://www.argyll-arcade.com, accessed on 27/03/2011.
[66] Service, A. (ed.) *Edwardian Architecture and its Origins*, London, 1975. p.193.

Plate 1.2: 60-62 Buchanan Street

opus that quickly responded to the development of art and public taste from Victorian to Modern architecture. He successfully demonstrated how tall buildings could be designed on Atlantic Chambers (1899) at 43-47 Hope Street[67], a commercial building with a ground floor and 6 storeys. Its large facade provided a surface on which the historical decorative repertoire was used to make a dynamic composition, topped with shaded loggias. The massive roof cornice is split by a vertical accent that rises from the ground floor level. There was no hesitation in introducing elements that assist in creating a balanced composition and in experimenting with their relationships. Burnet’s prediction of the future development of architecture is visible on the Kodak Building (1910-11, Kingsway, London) whose structure is expressed on the facades through the rhythm of columns accompanied by large glass surfaces and simple parapets between them[68].

60-62 Buchanan Street, a commercial building (former North British Rubber Building) designed by Robert Thomson (with Andrew Wilson assisting) in 1894-96[69].

The red sandstone main elevation (Plate 1.2)[70], topped with a stepped gable, shows influences of Dutch town houses. Symmetrically placed sculptures at the upper part draw attention towards the dynamic forms above them. Semi-elliptical and semi-circular windows at top floors and narrow bays on the elevation towards the side lane had been used on other buildings in Glasgow’s city centre and were later reinterpreted on the Lion Chambers. The architect Robert Thomson (c. 1854-c. 1914) practiced in Glasgow from 1880.[71] Nothing is known about his education or that of his business partner Andrew Wilson (c.1870-?)[72]. They also designed a former Glasgow Evening News Offices and the Printing Works at 67 Hope Street (1899-1907)[73] in a si-

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[67] Extract from Statutory List, Glasgow City Council, HB number 33050, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[68] Fletcher, B. Sir, *A History of Architecture*, Twentieth Edition, Architectural Press, Oxford, 1996, p. 1340.
[69] Extract from Statutory List, Glasgow City Council, HB number 32635, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011.
[70] Extract from Statutory List, Glasgow City Council, HB number 32635, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[71] Dictionary of Scottish Architects, Robert Thomson, http://www.scottisharchitects.org.uk, accessed on 01/04/2011.
[72] Dictionary of Scottish Architects, Andrew Wilson, http://www.scottisharchitects.org.uk, accessed on 01/04/2011.
[73] Extract from Statutory List, Glasgow City Council, HB number 33051, Category B. Available at www.glasgow.gov.uk, accessed on 23/03/2011

milar way, but with two bays on upper floors as the building site was wider.

164A-168 Buchanan Street, a commercial building designed by John Archibald Campbell in 1898

The building (Plate 1.3) stands opposite the Athenaeum Theatre, but its design is closer to the above building by Robert Thomson than to J. J. Burnet's. In 1877, at the age of eighteen, John Archibald Campbell (1859-1909)[74] started his architectural education in the office of John Burnet Sr (1814-1901)[75], a self-taught architect who designed a range of buildings in different historical styles such as the reconstruction of the Union Bank at 30-40 St Vincent Place (1870-73)[76], Merchants' House at 7 West George Street (1874-78)[77], Glasgow Stock Exchange at 159 Buchanan Street (1875-7)[78] and Lanarkshire House (now *The Corinthian*), 191 Ingram Street (1876-9)[79]. The architect John James Burnet, son of John Burnet Sr, returned from the atelier of Jean Louis Pascal (1837-1920) in Paris to his father's office also in 1877, and in 1880 took Campbell to Pascal's atelier. Campbell was admitted to the École des Beaux-Arts and returned to the Burnet practice in 1883, and became a partner in 1886 in John Burnet, Son & Campbell.[80] The partnership was dissolved in 1897. Campbell later designed a tall red stone office building at 157-167 Hope Street with asymmetrical elevation to West George Street (1902)[81], south of the Lion Chambers. Campbell's Northern Insurance Building at 84-94 St. Vincent Street (1908)[82] stands on a wider plot and has a ground floor and six storeys. The composition of the large facade topped with protruding roof cornices, which are divided in two sections by a central tower, is a reinterpre-

Plate 1.3: 164A-168 Buchanan Street

[74] Dictionary of Scottish Architects, John Archibald Campbell, http://www.scottisharchitects.org.uk, accessed on 01/04/2011.
[75] Dictionary of Scottish Architects, John Burnet (senior), http://www.scottisharchitects.org.uk, accessed on 01/04/2011.
[76] Extract from Statutory List, Glasgow City Council, HB number 32841, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[77] Extract from Statutory List, Glasgow City Council, HB number 32689, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[78] Extract from Statutory List, Glasgow City Council, HB number 33089, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[79] Extract from Statutory List, Glasgow City Council, HB number 32735, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[80] Dictionary of Scottish Architects, John Archibald Campbell, http://www.scottisharchitects.org.uk, accessed on 01/04/2011.
[81] Extract from Statutory List, Glasgow City Council, HB number 33053, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[82] Extract from Statutory List, Glasgow City Council, HB number 33153, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011

Plate 1.4: 144 St Vincent Street, Hat-rack, in 1899-1902, designed by James Salmon Jr

tation of J. J. Burnet's Atlantic Chambers (1899) at 43-45 Hope Street, but the large windows without frames and architraves from the third to fifth floor and on the side aisles show that Campbell's vision of the future development of architecture was similar to J.J. Burnet's.
The rear facade of the Northern Insurance Building has towering bays of steel-framed windows, resembling the north facade of Salmon Jr's Mercantile Chambers (1897) at 39-69 Bothwell Street and of the Lion Chambers (1907). Shallow bay windows on facades facing narrow lanes in Glasgow's city centre have since become almost a standard solution.

144 St Vincent Street, Hat-rack, in 1899-1902[83], designed by James Salmon Jr.

In contrast with the heavy stone facades of the above buildings, James Salmon Jr's first tall building looks light and transparent with its huge glass surfaces (Plate 1.4). This striking visual difference is due to the innovative structural system of steel frames that carry the building load. As the front facade did not need to carry the weight of the floors, it was constructed as a 'curtain wall'. This structural invention enabled the use of large windows and slim pilasters between them. Traditional bay windows with stone parapets were transformed into glass lanterns projected into open space, including two individual semi-circular oriel windows above the entrances. The lightness of the facade led to a playful composition of windows, cornices and balconies, finishing with a hat-rack like top that was responsible for the building's name. The main entrance has a marble finish on the floor and lower half of the walls, and leads towards an intricately decorated wrought-iron lift shaft.

1.2.1 Salmon Son & Gillespie Architects

A set of thirteen plans of the Lion Chambers, dated from April 1904 until January 1906, bear the signature Messrs. Salmon & Son & Gillespie Architects.[84] As James Salmon Jr represented

[83] Extract from Statutory List, Glasgow City Council, HB number 33160, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011
[84] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, March 1905. *Proposed Building Hope Street for Wm Geo Black Esq.* The Mitchell Library Archive, Glasgow

the third generation of architects in his family, the architectural opus, professional and social links of his grandfather James Sr and father William Forrest were an inherited background for learning and finding his own place as an architect. Both James Sr and William Forrest Salmon were leading figures and influenced the development of the architectural profession in the West of Scotland. A brief overview of the family's professional, social and cultural legacy is presented. This is followed by an overview of James Salmon Jr's education and experience before joining his father's firm. John Gaff Gillespie's education is briefly presented before providing an overview of his collaboration with James Salmon Jr.

James Salmon Sr (1805-1888) initially worked with John Brash (c.1775-1848), a Glasgow architect. Brash designed buildings at Blythswood Square (1823-29) whose general arrangement was determined by a plan made by Gillespie Graham (1776-1855) in 1820.[85] The square emulated the scale and architecture of Edinburgh's Georgian New Town. Between 1825 and 1830, Salmon Sr opened his own office.[86] In 1843, he formed a partnership with the architect Robert Black which lasted until 1854 under the name Black & Salmon. In 1849, he designed St Matthew's Church in Bath Street (destroyed by fire in 1952 and demolished)[87] and a Renaissance warehouse at 81 Miller Street (1849-50)[88] for the art collector Archibald McLellan (1795-1854), the founder of the McLellan Galleries.[89] In 1854, Salmon Sr designed a housing scheme in Dennistoun[90], the area where he lived, that was partly built in the 1860s.[91] He was also a property developer and an estate agent.[92] In the 1850's, he was active in promoting the Glasgow Architectural Exhibition in 1853[93] and assisted in founding the Glasgow Architectural Society in 1858[94] as proposer and first Vice-President. In 1868, he became first President of the newly founded Glasgow Institute of Architects whose Vice-President was Alexander Thomson (1817-1875).[95] Salmon Sr was politically active and rose to the position of a Baillie[96] of the City[97], contributing to the development of better housing for the working classes.[98]

[85] Dictionary of Scottish Architects, John Brush, http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[86] Walker, D. M, Salmon, Son, Grandson and Gillespie, *Scottish Art Review*, 1966, Vol. X, no. 3, p. 17.
[87] The Glasgow Story, St Matthew's Highlanders Memorial Church. At http://www.theglasgowstory.com, accessed on 25/03/2011.
[88] Extract from Statutory List, Glasgow City Council, HB number 32759, Category A. Available at www.glasgow.gov.uk, accessed on 23/03/2011.
[89] MacLehose, J. (1886) *Memoirs and portraits of one hundred Glasgow men.* Archibald McLellan. Glasgow Digital Library, http://gdl.cdlr.strath.ac.uk. accessed on 25/03/2011.
[90] Edinburgh University Press, 1993, p. 79.
[91] Walker. D. M., 1966, p.18.
[92] O'Donnell, R., The Wee Troot: *Letters to New Zealand, James Salmon, architect*, Architectural Heritage, November 2008, Vol. 19, no. 1, p. 30. At http://www.euppublishing.com, accessed on 25/03/2011.
[93] For an overview of this predecessor of The Lighthouse, Scotland's Centre for Architecture and Design see Stamp, G. and McKinstry, S. (eds.) *'Greek' Thomson*, Edinburgh University Press, 1994, pp. 17-20.
[94] The Glasgow Institute of Architects has its origins in the Glasgow Architectural Society, the members of which first met in Alexander Thomson's Scottish Exhibition Rooms in Bath Street on 14 January 1858 to establish a society for Glasgow and the West of Scotland. The Glasgow Institute of Architects, www.gia.org.uk, accessed on 25/03/2011.
[95] Dictionary of Scottish Architects, James Salmon (senior). At http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[96] A baillie (alternative spelling bailie, from Old French) was a local civic officer in Scottish burghs, approximately equivalent to the post of alderman or magistrate (bailiff). They were responsible for a jurisdiction called a bailiary (alt. bailiery).
[97] O'Donnell, R., 2008, p.30.
[98] Edwards, B., Glasgow Improvements, 1866-1901, in Reed, P. (ed.) *Glasgow: The forming of the City*, Edinburgh University Pres, Edinburgh, p. 94.

William Forrest Salmon (1843-1911) started architectural apprenticeship with the architect James Smith (1808-1863) around 1857. There he met William Scott Morton (1840-1903) and followed him to George Gilbert Scott's (1811-1878) office in London. He returned to Glasgow around 1866 and became a partner in his father's firm along with James Ritchie (1835-1910). The practice name was Salmon, Son & Ritchie until 1872, when Ritchie left, and the practice name was changed to James Salmon & Son.[99] William's links with Morton strengthened in 1872 when he married Jessie Alexander (1843-1887), a younger sister of Morton's wife Elizabeth.[100] Through this link the practice maintained contacts with London as the Scott Mortons[101] expanded their business in furniture, oriental carpets, upholstery and wall paper first to the capital and then to New York in 1889. The circle of artistic interests in the family extended after William Forrest's sister Helen Russell Salmon married the Yorkshire-born animal painter Tom Hunt. With his London friend Axel Haig (1835-1921), famous for his architectural etchings[102], William Forrest went on his first visit to Italy.[103] He was also a friend of William McTaggart (1835–1910)[104], the leading Scottish landscape painter of his lifetime, and the sculptors Derwent Wood (1871-1926), Albert Hodge (1875-1917) and Johan Keller (1863-1944).[105]

With his father, William Forrest was also a founder member of the Glasgow Institute of Architects in 1868 and later its President. As his father, William Forrest was also a successful businessman.[106] He was a Governor at the School of Art in 1893-1910; during this period he undertook a number of roles and sat on a variety of sub groups. He also acted as an Examiner and a Visiting member of staff in various capacities between 1893 and 1910.[107] He was a close friend and supporter of Francis Henry Newbery (1855-1946), the Headmaster of the School of Art from 1885 until 1918, and his development of its Arts and Crafts credo

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99 Dictionary of Scottish Architects, James Salmon (senior). At http://www.scottisharchitects.org.uk, accessed on 25/03/2011.

100 Dictionary of Scottish Architects, James Salmon & Son. At http://www.scottisharchitects.org.uk, accessed on 25/03/2011.

101 In 1870 William Scott Morton (1840-1903) and his brother John set up the Morton and Co furniture business in the Tynecastle area of Edinburgh. As a young man William attended decorative design classes in Glasgow and was apprenticed to the Glasgow architect James Smith. He had gained experience from several jobs in London, including work in the 1860s at Johnstone, Jeanes and Co furnishings, New Bond Street. As well as producing furniture, Morton and Co stocked oriental carpets and other upholstery. In the 1870s the firm began to make wallpaper, and became renowned for their invention of Tynecastle Tapestry, a canvas wall covering inspired by 15th-16th century Spanish and Italian embossed leather wall hangings. The 3-D nature of the canvas and the revolutionary way in which it was made meant that it was a more economic, lighter, yet durable, alternative to plasterwork. Tynecastle Tapestry was ideal for frieze decoration, ceilings and ships' saloons as well as walls. From the late 19th century onwards Scott Morton and Co provided furnishings and fixtures for many prestigious houses including 25 Learmonth Terrace, Edinburgh; Norwood House, Aberdeen; and Holyrood Palace, Edinburgh. Royal Commission on the Ancient and Historical Monuments of Scotland, Canmore, Scott Morton, http://canmore.rcahms.gov.uk, accessed on 25/03/2011.

102 At the end of the nineteenth and at the beginning of the twentieth century, Axel Hermann Haig was one of Britain's most famous etchers. Haig, however, was actually born and raised on Gotland Island, Sweden, and initially studied naval architecture. Later, he settled in London and began working for several architects. Haig studied etching in his spare hours and within several years began producing the large architectural views that made him famous. His art in this medium quickly gained national recognition and Axel Haig became a regular exhibitor at the prestigious Royal Academy. He was also a full member of the Royal Society of Etchers and Engravers. Art of the Print. Axel Hermann Haig, www.artoftheprint.com, accessed on 25/03/2011.

103 Dictionary of Scottish Architects, James Salmon & Son, At http://www.scottisharchitects.org.uk, accessed on 25/03/2011.

104 O'Donnell, R., 2008, p.30.

105 Walker, D. M., 1966, p. 19.

106 O'Donnell, R., 2008, p.31.

107 The Glasgow School of Art, Annual Reports (GSAA/GOV/1), 1878-1910, The Glasgow School of Art Archives and Collections Centre. During the 19th century Headmasters (Directors) of Glasgow School of Art were Henry Macmanus, 1844-1848; Charles Heath Wilson, 1849-1864; Robert Greenlees, 1863-1881; Thomas C Simmonds, 1881-1885; Francis Henry Newbery, 1885-1918, Ibid.

and curriculum.[108] As the practice reputation was high, the leading figures in late nineteenth century Scottish architecture worked there, including James Marjoribanks McLaren (1843–1890) and Sir George Washington Browne (1853–1939). As William Forrest returned from London to his father's office in 1866, he could have contributed to the design of the Franco-Italian gothic former Deaf & Dumb Institute, Langside (1866–8).[109]

Changes in the architectural outputs of the practice appeared through the works of John Gaff Gillespie and James Salmon Jr. At the start of the 20th century the practice became 'one of the most stylistically visionary in Glasgow, if not Britain, and one whose work was reported upon favourably in the English, French and German press' as 'the firm's work proceeded to traverse between the dusk of the Victorian age through to the dawning of the Edwardian, migrating from the era of traditional loadbearing masonry construction, through the advent of the steel frame and the development of the cantilever, ultimately concluding with the monolithic structural system of reinforced concrete.'[110] This transformation of the practice output was supported by William Forrest Salmon. Although not an innovative architect himself, Forrest Salmon had an insight into emerging changes in architecture through the engagement with the School of Art in which Francis Henry Newbery supported the students to explore and innovate. Forrest Salmon's awareness of the times to come is explicit in a talk given in 1893:

"At the present time there exists a strong tendency to advance in architectural development. A spirit of dissatisfaction with the later productions is everywhere manifesting itself, and a true appreciation of what architecture is appears to be taking possession of a thoughtful section of the public. Those practising architecture have become aware that it will not suffice to plan a building, and then clothe its nakedness in the architectural details of a Greek temple or a Gothic cathedral, but that each building must be a living expression of its own uses. If it is to exist as an abiding work of art, it must tell its story not only to its own generation, but to the generation following."[111]

James Salmon Jr (1873-1924) was initially educated privately and sent to Glasgow High School in September 1883, remaining there until 1888 when he joined the family firm for two years[112]. In 1887, his mother died suddenly[113] and then his grandfather James Salmon Sr died on 5 June in 1888 'when walking home after giving one of his celebrated after-dinner speeches.'[114] His father remarried in 1889 to Agnes Cooper Barry, who brought with her a much younger sister Charlotte, but Salmon Jr and his younger brother Hugh were not fond of Agnes, referring to her as 'Steppy'. Hugh left the family home in 1894 to work for

[108] Gateway to Archives of Scottish Higher Education, Francis Henry Newbery. http://www.gashe.ac.uk, accessed on 26/03/2011
[109] O'Donnell, R., 2008, p.31.
[110] Ibidem, p.31.
[111] Salmon, W. F., The Master Wright and the Architect, in *Glasgow Advertiser and Property Circular*, 19 December 1893. Quoted here from O'Donnell, 2003, p. 37.
[112] Dictionary of Scottish Architects, James Salmon & Son, http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[113] Ibidem.
[114] Ibidem.

his maternal grandfather at Arrat Mill, Brechin, Aberdeenshire[115], and then, in 1898, emigrated to New Zealand.[116]

In 1890, Salmon Jr's architectural apprenticeship continued in the office of the architect and artist William Leiper (1839-1916), a close friend of his father.[117] Leiper's architectural production was a lively mix of styles such as Franco-Scottish on Colearn castle in Perthshire (1869-74), Dalmore in Helensburgh (1873), and Kinlochmoidart, Inverness-shire (1884); Anglo-Japanese interiors in Cairndhu, Helensburgh (1871); and arts-and-crafts and Scots baronial at Endrick Lodge, Stirling (c.1900). Leiper was also a talented painter who exhibited works in watercolour and oil as well as architecture from 1870 onward, and was elected associate of the Royal Scottish Academy in 1891 and full member in 1896. He is also mentioned as the interior designer of the steam yacht 'Livadia'.[118] Leiper's flamboyant style is evident on the polychrome red stone, brick and tile Venetian Gothic Templeton Factory at 62 Templeton Street (1889)[119] and the huge Sun Insurance Building at the corner of 117-121 West George Street and 38-42 Renfield Street in style of Francois Ier (1893-94).[120] The latter received a Silver Medal at the Paris Exhibition of 1900.[121]

As Salmon Jr worked on the drawings for the Sun Insurance Building, the award must have been a boost to his professional aspirations. He might have visited the Paris Exhibition 1900 and seen reinforced concrete buildings exhibited by Hennebique and other engineers.

While in Leiper's office, Salmon Jr worked under the direction of William James Anderson (1864-1900) on Glasgow Green (1888-1892) and probably saw Anderson's project for the Orient Building (1892-95) in which reinforced concrete floors and ceilings and flat roof were used.[122] Salmon Jr worked in a friendly studio atmosphere in Leiper's office 'whose staff were often invited home, particularly at the time of the strawberry crop, and taken on a cycling tour'.[123] He left Leiper's office in 1894,[124] but Leiper's imaginative and daring approach to architectural design is recognisable in his later projects.

In April 1894, when Salmon Jr was twenty one, he received from his father an appropriate birthday present for an aspiring young architect - a Grand Tour (from Pisa to Venice in Italy and Lucerne in Switzerland)[125] during which he painted watercolours between April and July of that year. In 1895, he completed his prolonged studying at the Glasgow School of Art which he had started in 1889[126] and began working in the family firm where John Gaff Gillespie, three years older than Salmon Jr, was in charge of most of the design work.[127]

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115 O'Donnell, R., *The life and work of James Salmon Architect*, 1873-1924, The Rutland Press, London 2003, p. 31.
116 Ibidem, p. 41.
117 O'Donnell, R., 2008, p. 31.
118 Cochrane, H., op. cit., p. 51.
119 Extract from Statutory List, Glasgow City Council, HB number 33857, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011
120 Extract from Statutory List, Glasgow City Council, HB number 33223, Category A, http:// www.glasgow.gov.uk, accessed on 23/03/2011
121 Dictionary of Scottish Architects, William Leiper, http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
122 Blaikie, G. Victorian Glasgow. Commercial Buildings, http://www.scotcities.com, accessed on 25/03/2011.
123 Ibidem.
124 Dictionary of Scottish Architects, James Salmon & Son, http://www.scottisharchitects.org.uk, accessed on 25/03/2011
125 O'Donnell, R., *The life and work of James Salmon Architect*, 1873-1924, The Rutland Press, London 2003, p. 34.
126 Dictionary of Scottish Architects, James Salmon & Son, http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
127 Ibidem.

At the time when James started studying at the Glasgow School of Art, Francis Henry Newbery held the post of Headmaster since 1885 and led the school successfully until 1918. The School became internationally acclaimed following the work of its graduates such as the architect and designer Charles Rennie Mackintosh; the designers Margaret Macdonald (1864-1933) and Frances Macdonald (1873-1921); the artist and designer Herbert McNair (1868-1955); the painter and illustrator Jessie M. King (1875-1949) and others working in the 1890s in Glasgow.[128]

As Charles Rennie Mackintosh started attending either early morning or late evening classes at the Glasgow School of Art from 1883 and enrolled as a student each year until 1894[129], he could have met James Salmon Jr, who had also studied there from 1889 until 1895, and John Gaff Gillespie who started his studies in 1884 and won the Glasgow Institute of Architects prize in 1889 jointly with Mackintosh.[130] In 1892 and 1893, Mackintosh and Salmon Jr exhibited their sketches and watercolours at the Glasgow Institute of the Fine Arts.[131]

In 1897, James' younger brother Hugh Alexander Salmon (1874-1960) went to New Zealand where he stayed and kept contact with James through letters for many years.[132] James' letters were accompanied with sketches, some of architecture, others as symbolic vignettes of his longing for Hugh's letters, e.g. a cartoon sketch of both of them at the opposite ends of an elongated oval table (which could represent the Earth) writing to each other and waiting six weeks for a letter to arrive from Glasgow to New Zealand and six weeks for a reply (dated Monday, 10th September 1900). Hugh Alexander treasured his brother's letters and kept a Journal in which he colleted them.[133]

The development of a friendship between Salmon Jr and Mackintosh was also influenced by the departure of the artists James Herbert MacNair (1868-1955) and Frances Macdonald (1873-1921), his wife and the sister of Margaret Macdonald (1864-1933), to Liverpool in 1898. Until then, Mackintosh, MacNair and the Macdonald sisters, who all met at the School of Art and had similar ideas on art, closely collaborated and were known as The Four[134]. Salmon Jr wrote to his brother in April 1899 that Mackintosh was engaged to be married to Margaret Macdonald and had come to Salmon's new family home Rowantreehill in Kilmacolm to stay over Sunday. At that time Mackintosh was designing Windyhill (1899-1901), a house on a plot of land adjacent to Rowantreehill, and could have also come later to check the progress.[135]

It had been noted that Salmon Jr won a larger share of the market among those prepared to build stylistically adventurous houses than Mackinotsh, including a series of houses at Kilmacolm whose interiors were a simplified version of Mackintosh style with inventive light fittings

[128] Gateway to Archives of Scottish Higher Education, Francis Henry Newbery. http://www.gashe.ac.uk, accessed on 26/03/2011

[129] Kaplan, W. (ed), Charles Rennie Mackintosh, Glasgow Museums and Abbeville Press Publishers, New York-London-Paris, 1996, p.17.

[130] Dictionary of Scottish Architects, James Salmon & Son, At http://www.scottisharchitects.org.uk, accessed on 25/03/2011.

[131] Robertson, P. The Making of a Painter. In Kaplan, W. (ed) *Charles Rennie Mackintosh*, Glasgow Museums and Abbeville Press Publishers, New York-London-Paris, 1996, p. 294.

[132] O'Donnell, R., 2008, Vol. 19, no. 1, pp. 28-51. At http://www.euppublishing.com, accessed on 25/03/2011.

[133] Op. cit., p.29.

[134] The Department of Decorative Art, Glasgow Museums and Art Galleries, *The Glasgow Style 1890-1920*. Glasgow Museums and Art Galleries, Glasgow, 1984, p. 38.

[135] O'Donnell, R., *The Wee Troot: Letters to New Zealand, James Salmon, architect*, Architectural Heritage, November 2008, Vol. 19, no. 1, p. 41, http://www.euppublishing.com, accessed on 25/03/2011

designed by Salmon Jr himself.[136] One of Salmon Jr's designs in Kilmacolm is the extension of a late-Victorian villa on Gryffe Road whose plans were submitted early in 1906, incorporating certain forms and details which had appeared the previous year in the concrete tower of the Lion Chambers.[137] Archibald Ferguson, a lawyer who had an office in the Lion Chambers, commissioned Salmon Jr to design his house, Nether Knockbuckle, in Kilmacolm in 1907, on which architectural expression was simplified more than ever before.[138]

The friendship between Salmon and Mackintosh led to mutual influences in architecture. Mackintosh's influence in the design of Salmon's and Gillespie's hall of St Andrew's-in-the-East Church in Alexandra Parade, in Glasgow (1899) has been suggested.[139] These influences emerged from some overlaps in their design philosophies. Their public lectures provide insights into what they considered important in design and enable a better understanding of their architecture. The freedom of architectural design was the reason for John Ruskin's (1819-1900) passionate love for Gothic architecture. His books, such as The Stones of Venice (1851-53), were read again. Mackintosh quoted Ruskin in his first lecture on contemporary architecture (around 1892):

"…And it is one of the chief virtues of the Gothic builders that they never suffered ideas of outside symmetries and consistency to interfere with the real use and value of what they did. If they wanted a window they opened one; a room, they added one; a buttress they built one; utterly regardless of any established conventionalities of external appearance knowing (as indeed it always happened) that such daring interruptions of the formal plan would rather give additional interest to its symmetry than injure it."[140]

Asymmetrical design of building form and facades, and purpose-directed placement of windows are also present in Scottish vernacular architecture and its academic interpretations. In his second lecture Mackintosh wrote that 'all great and living architecture has been the direct expression of the needs and beliefs of man at the time of its creation' and that 'to get architecture the architect must be one of a body of artists possessing an intimate knowledge of the crafts.'[141] However, Mackintosh had not followed the first idea as far as Salmon had through the experimentation with steel and reinforced concrete structures.

In 1908, Salmon Jr gave a lecture to the Glasgow Institute of Architects on 'The Decoration of Steel and Reinforced Concrete Structures', indicating the approach taken in designing the Lion Chambers:

"The Scottish style, I mean especially that of the old rough-cast castle, is eminently adapted to a development suited to reinforced concrete construction – the plain rough-cast surfaces, extending to the window sashes, and simple corbelling, the small cornices, the straight lines,

[136] Walker, D., 1996, p.146-7.
[137] Walker, F. A., Six Villas by James Salmon, *Architectural History*, 1982, Vol. 25, p. 115.
[138] Ibidem, p. 117.
[139] Walker, D., The Partnership of James Salmon and John Gaff Gillespie, in Service, A. (ed.), *Edwardian Architecture and its Origins*, London, 1975, p. 240.
[140] Ruskin, J., The Works of John Ruskin, 39 vols., ed. E. T. Cook and Alexander Wedderburn, London, 1902-12, vol. 10, p. 212, quoted here from Walker, D., 1996, p. 132.
[141] Walker, D., 1996, p. 133.

the rarity of arches, and other details difficult to construct: Above all, the freedom to do anything you like provided the shapes suit your material wants, and group well with the natural surroundings. Ruskin is fundamentally wrong when he says that architecture must be carefully distinguished from building. Building is architecture. If this new material, reinforced concrete, could induce us to drop all the ridiculous accretion of absurdities which we plaster on to stone, it will indeed have lifted a weight from a world overladen with "ornaments" and "decorators"'.[142]

Salmon Jr also gave lectures to architecture students at the School of Art and the Liberal and Art Clubs.[143] Throughout his career, Salmon Jr was an active participant of the contemporary art, urban and architectural scene, and in political circles; he was a member of the Scottish Society of Art Workers, the Glasgow Art Club, the Chelsea Arts Club, the Garden City Association, the Liberal Club, the Wrights and the Hammermen, and the first editor of the journal of the Royal Incorporation of Architects in Scotland from its incorporation in 1922 until his death in 1924.[144] Salmon Jr's architectural designs stood alone among all of the Glasgow Style designers in its affinity with Continental Art Nouveau and the emerging Modern Movement.[145] Historians of architecture agree that of Mackintosh's contemporaries the nearest to him in spirit was James Salmon Jr.[146] The careers of the two friends ended in a similar way as 'sadly, after the Edwardian decade Glaswegians seemed no longer to be impressed by what Mackintosh – or, for that matter, his friend James Salmon Jr – had to offer'.[147]

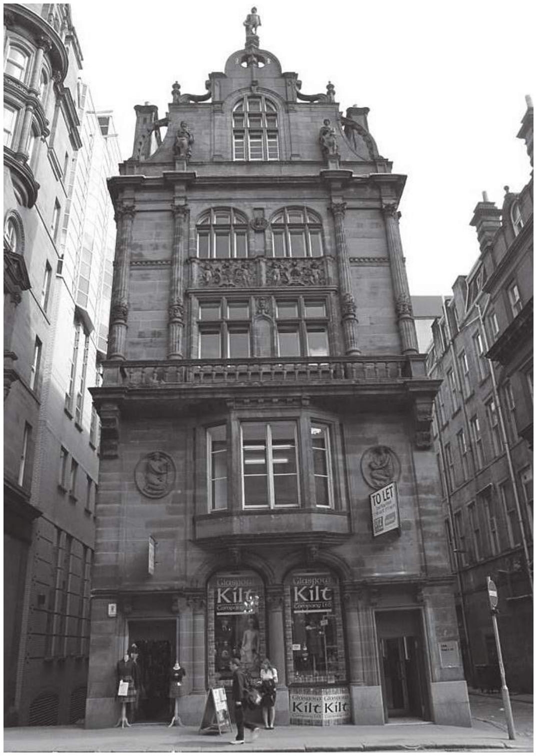
Salmon Jr's letters to his brother also provide evidence of friendly relationships with artists Tom Hunt (who was married to his father's sister), painter G. G. Anderson, painter and illustrator Stewart Orr (1872-1944), Roy Orr, Norman McLean, and the writer Neil Munro (1863–1930). Munro edited the Glasgow newspaper The Evening News, for which James contributed articles and cartoons.[148] O'Donnell (2008) wrote:

"James's letters to his brother reveal the whole man. The words, their phrasing, their handscript styling, the layout, the subject matter, the aesthetic and the sheer variety, humour, and character of the sketches, bring his spirit to life. His humanity, wit and personality beam off the pages and it is impossible to isolate the man from his art."

For his lively character and a small stature, James was affectionately known as the 'Wee Troot' (a small trout). For his unorthodox political views, he was described as 'a social and municipal Bolshevik… his views on the Parish Council, School Board, and Infirmary Managers cannot be published!'[149] Salmon Jr's dynamism and daring views are embedded in the design of the "strange 'Hat-rack' building and astonishing

[142] *Builder's Journal,* 25 March 1908, pp. 269-73., quoted here from Collins, P., op. cit., p. 83.
[143] O'Donnell, R., 2003, p. 42.
[144] The Department of Decorative Art, Glasgow Museums and Art Galleries, *The Glasgow Style 1890-1920*. Glasgow Museums and Art Galleries, Glasgow, 1984, p. 46.
[145] O'Donnell, R., 1990, p. 35.
[146] Gomme, A. and Walker, D., op. cit, p. 221.
[147] Stamp, G. The London Years, in Kaplan, W. (ed), *Charles Rennie Mackintosh*, Glasgow Museums and Abbeville Press Publishers, New York-London-Paris, 1996, p. 222.
[148] O'Donnell, R., 2008, p. 41. At http://www.euppublishing.com, accessed on 25/03/2011
[149] Walker. D. M., 1966, p. 20.

Plate 1.5: 108 Hope Street, Scottish Temperance League



Lion Chambers in Glasgow (which) are among the most interesting buildings of the Edwardian period.”[150]

John Gaff Gillespie (1870-1926) did not have a privileged start in life like Salmon Jr; he was the eldest of at least nine children of Alexander Gillespie, a Gorbals baker who originated from Duntocher, and his wife Margaret Gaff from Polmont.[151] Gillespie had been an apprentice at the practice of James Milne Monro (1840-1921) from 1886 to 1891 while attending classes at the School of Art.[152] As he won the Glasgow Institute of Architects prize in 1889 jointly with Mackintosh, William Forrest Salmon noticed him and employed in his firm in 1891. He was entrusted with the design of the Scottish Temperance League building at 108 Hope Street (1893-4)[153] (Plate 1.5) which was designed in free Flemish Renaissance style, Pl. 5. His next project was the West of Scotland Convalescent Seaside Homes at Dunoon in 1895. From that year, Gillespie became a partner in the firm.[154]

Professional collaboration of James Salmon Jr and John Gaff Gillespie

This brief overview of the professional collaboration of Salmon Jr and Gillespie includes only major projects.[155] In 1895, when Gillespie became a partner in W. F. Salmon’s practice, Salmon Jr joined his father’s firm. He became a partner in 1898, but neither his nor Gillespie’s name was acknowledged in the practice title until November 1903 when the firm became Salmon, Son & Gillespie.[156]

In letters to his brother, Salmon Jr wrote how the practice operated – each partner retained responsibility for certain work or clients.[157] Change of the practice name to Salmon, Son & Gillespie in 1903 was explained as a progressive step. Salmon Jr and Gillespie undertook many trips together for study and leisure. They

[150] Walker, D., Scotland At The End Of The Century, in Service, A. (ed.), *Edwardian Architecture and its Origins,* London, 1975, p. 186.
[151] Dictionary of Scottish Architects, John Gaff Gillespie, http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[152] Ibidem.
[153] Dictionary of Scottish Architects, James Salmon & Son, at http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[154] Dictionary of Scottish Architects, John Gaff Gillespie, at http://www.scottisharchitects.org.uk, accessed on 25/03/2011.
[155] A comprehensive list of all projects and competitions is provided in O’Donnell, R., 2003.
[156] Ibidem.
[157] O’Donnell, R., 2008, p. 39.

researched and travelled extensively to study examples of relevant contemporary buildings to inform the projects that they were undertaking.[158] They were friends with Ernest Archibald Taylor (1874-1951), a designer of furniture and Lecturer (1903-05) at the School of Art, and later a designer of stained glass windows, and a painter.[159] They also employed craftsmen such as John Crawford who had a woodcarving business with his brother, and produced woodwork for building and ship interiors, including a woodwork carved to designs by Salmon Jr and Gillespie that was displayed at exhibitions in Glasgow (1901), Turin and Budapest in (1902).[160]

The next project acquired by the practice, the Mercantile Chambers (1897) at 39-69 Bothwell Street (Plate 1.6), was entrusted to Salmon Jr. This red stone building was one of the largest steel-framed office blocks in Glasgow.[161] There is no indication of the nature of the internal structure on the elevation to Bothwell Street. Decorations on the main facades include some elements of international Art Nouveau and sculptures by Derwent Wood.[162] The real novelty is the elevation to Bothwell Lane which had eight bays of shallow, canted metal-framed windows rising full-height from the first floor (Plate 1.7). This design feature was reinterpreted on the north facade of the Lion Chambers. In 1897-99, Salmon Jr and Gillespie contributed to the design of the interior of 22 Park Circus in Glasgow (1872-74)[163]. The house is within the Park Circus terrace whose architect

Plate 1.6: Bothwell Street, Mercantile Chambers, front elevation

[158] Ibidem.
[159] The Department of Decorative Art, Glasgow Museums and Art Galleries, *The Glasgow Style 1890-1920*. Glasgow Museums and Art Galleries, Glasgow, 1984, p. 46, 48, 49.
[160] Ibidem, p. 16.
[161] Walker, D. M., 1966, p. 20; O'Donnell, R., Acquiring a Taste for Salmon, *RIBA Journal,* August 1990, p. 36.
[162] Extract from Statutory List, Glasgow City Council, HB number 32980, Category A. http:// www.glasgow.gov.uk, accessed on 23/03/2011.
[163] Extract from Statutory List, Glasgow City Council, HB number 32238, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011.

Plate 1.7: 39-69 Bothwell Street, Mercantile Chambers, back elevation

was Charles Wilson (1810-1863).[164] The sumptuously stuccoed and sculptured interiors were designed by James Boucher[165] (1826-1906).[166] New chimneypieces in the Art Nouveau style were installed with woodcarving executed by Derwent Wood. Several principal rooms, including a billiard room, were also designed in Art Nouveau style and are considered among the finest pieces of British Art Nouveau.[167]

In 1899, the practice was busy with the projects that introduced Art Nouveau details on elevations of the hall of St. Andrews-in-the-East in Alexandra Parade[168], the British Linen Bank at 816-818 Govan Road[169] and the Savings Bank at 752 Argyle Street[170]. Sculptures on the first bank were executed by Derwent Wood and Johan Keller, and on the second one by Albert Hodge.[171]

The fully blown Art Nouveau was developed in the design of the 'Hat-rack' building in Glasgow's city centre, Pl. 4. When it was planned, Salmon Jr wrote to his brother in 1899 that the practice 'will probably be starting the highest building in Europe' and sent a small sketch on the edge of the letter of the proposed building facade which resembles an early perspective sketch of the 'Hat-rack'.[172] He also commented on difficulties with the building authority to develop tall buildings and provided, as an example, information that the architect John James Burnet had two storeys cut off a proposed ten-storey building.[173] However, the warrant for the 'Hat-rack' was granted and the work started in July 1899.[174]

Building high was a new challenge for architects that led to an underlining competition that could be sensed from Salmon Jr's comment that the architect James Thomson (1835-1905) was designing a tall building almost opposite the 'Hat-rack' and that they were 'going to race him'.[175]

[164] Dictionary of Scottish Architects, Charles Wilson, http://www.scottisharchitects.org.uk, accessed on 09/04/2011.
[165] Walker, D. 1975, p. 242.
[166] Dictionary of Scottish Architects, James Boucher, http://www.scottisharchitects.org.uk, accessed on 09/04/2011.
[167] Walker, D. 1975, p. 242.
[168] Extract from Statutory List, Glasgow City Council, HB number 48569, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[169] Extract from Statutory List, Glasgow City Council, HB number 33351, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[170] Extract from Statutory List, Glasgow City Council, HB number 32953, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[171] Walker. D. M., 1966, p. 20.
[172] O'Donnell, R.,2008, p. 33. At http://www.euppublishing.com, accessed on 25/03/2011.
[173] Ibidem, p. 34.
[174] Ibidem, p. 34.
[175] Ibidem, p. 35.

However, Thomson's building at 199-123 St Vincent Street (1899) has only a ground floor, 5 storeys and an attic.[176] Another competitor in the race for taller buildings was John Archibald Campbell whose designs for red stone buildings with a ground floor and seven storeys, influenced by American architecture, were completed at 157-167 Hope Street[177] and 50 Argyle Street in 1905.[178]

With the basement, ground floor, seven storeys and attic, the 'Hat-rack' was the tallest building in Glasgow at that time.[179] The building attracted international attention - five pages were devoted to Salmon Jr's work in *L'Art Decoratif* in 1899.[180] Gillespie designed houses at 12-14 University Gardens around 1900, and in 1901 the practice won a competition for the former Congregational Church at 155-57 Rutherglan Road (demolished).[181] They were not successful with competition design for the Glasgow Technical College in 1901 with two versions of elevations, one in Renaissance style by Gillespie and the other in Art Nouveau style by Salmon Jr.[182] In 1902, the practice submitted two competition designs, for the Rutherglen Public Library and the Newton Park School in Ayr, but neither was selected.[183] In 1902-04, the partners designed a nurses' home at Woodilee Hospital[184] in Lenzie, near Glasgow (demolished).

In 1903, Salmon Jr and Gillespie remodelled the facade of an existing building at 79 West Regent Street with Glasgow's Art Nouveau details. This building stands at the corner with Hope Street, diagonally opposite to the offices of the lawyer William George Black, the client of the Lion Chambers. Before presenting this project in more detail, a brief overview is provided of the most important projects that followed before the practice was dissolved.

In 1904, Gillespie designed Lanfine Cottage Hospital, Broomhill, Kirkintilloch,[185] now derelict.[186] A series of five private houses in Kilmacolm, designed by Salmon Jr, also kept the practice busy.[187] The Salmons lived in Rowantreehill house, a family home since 1898, designed by Salmon Jr but owned by his father William Forrest. Rowantreehill house is a mixture of Scottish and English styles with some Art Nouveau details. The next house was Miyanoshita (1904) whose design signalled Salmon Jr's exploration of new approaches to the design of rural houses starting with simple forms and minimal Art Nouveau decorative accents. The extension of Northernhay, a late Victorian villa on Gryffe Road, in 1905, included a few details from the concrete tower on the Lion Chambers. The Tudor-inspired design of Hazelhope (formerly Dilkush) in 1906 returned to earlier inspirations for housing design, while the Den o'Gryffe house (1905) shows influence of Charles Voysey (1857-1941)[188], English Arts

[176] Extract from Statutory List, Glasgow City Council, HB number 33139, Category B, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[177] Extract from Statutory List, Glasgow City Council, HB number 33053, Category A, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[178] Extract from Statutory List, Glasgow City Council, HB number 32611, Category B, http://www.glasgow.gov.uk, accessed on 23/03/2011.
[179] Walker, D. M, 1966, 21.
[180] Ibidem.
[181] Ibidem.
[182] Walker, D., 1975, p. 242.
[183] Ibidem.
[184] Ibidem.
[185] Ibidem, p. 245.
[186] Buildings at Risk, Register for Scotland, Broomhill Hospital (former), http://www.buildingsatrisk.org.uk, accessed on 09/04/2011.
[187] Walker, F. A., op.cit., 114-119.
[188] Ibidem, p. 116.

and Crafts architect and designer. However, the extension of Den o'Gryffe house in 1907 demonstrated that Salmon Jr's explorative design approach was directed towards simplification of form and detail. The simplicity of design of the Den o'Gryffe house (1905-07), followed the work on the Lion Chambers on which Salmon Jr proposed a version of an office building stripped of decoration, but imbued with Scottish architectural tradition in its forms and the truthful expression of building materials. Archibald Ferguson, one of the lawyers who had an office in the Lion Chambers, commissioned Salmon Jr to design the Nether Knockbuckle house in Kilmacolm whose architectural expression had been simplified more than in any previous house design[189], demonstrating another step in the direction of the Modern Movement. The house in Edzell (Angus), designed by Salmon Jr in 1906, offered an Arts and Crafts version of the Scottish style[190] in a compact form built of red stone rubble[191].

The practice proposed a reinforced concrete structure in the competition projects for the Mitchell Library in Glasgow (1905) in Renaissance style and the Glamorgan County Offices (1909) in Free Baroque style which were not won.[192] In 1906-08, the practice designed a school at Cartsburn, Greenock, destroyed in the Second World War.[193] In 1907, Salmon Jr participated unsuccessfully in the design competition for the Glasgow Liberal Club with a huge cube whose facades were divided by colossal columns above the first floor and bay windows between them.[194] The proposed building form and articulation of elevations, although more restrained, were present in J. J. Burnet's design for the McGeoch's Ironmongery Store in West Campbell Street (1905)[195], now demolished.[196] The competition designs for the London County Hall and the Perth City Hall in 1907, the Hamilton New Academy and the extension of Rutherglen Town Hall in 1909 were all liberal interpretations of historic styles, but had not been selected. Gillespie was successful with his competition design for the Stirling Municipal Buildings in 1907[197], inspired by Scotland's early 16th century architecture, and for the Pollock Golf Clubhouse in 1911.[198] The practice used reinforced concrete structure and brick block for the west extension of the Cranstonhill Bakery, 38-42 Cranston Street, in 1912 (demolished in 1969).[199] The use of brick block instead of concrete panels raises a question of whether at that time the partners had understood that concrete without thermal insulation was not suitable for external walls.

As there was little interest for innovative design of public buildings, the partners returned to historical styles in competition designs. However, just as Salmon Jr, Gillespie was also interested in new design approaches and building

[189] Ibidem, p. 117.
[190] Walker, D., 1975, p. 245.
[191] Scotland's Places, Edzell, 36 Church Street, North Lodge, http://www.scotlandsplaces.gov.uk, accessed on 09/04/2011.
[192] O'Donnell, R., 2003, p. 46.
[193] Walker, D., 1975, p. 245.
[194] Ibidem, p. 247.
[195] Perspective drawing in O'Donnell, 2003, p. 15.
[196] Dictionary of Scottish Architects, (Sir) John James Burnet, http://www.scottisharchitects.org.uk, accessed on 10/04/2011.
[197] British Listed Buildings, 8 and 10 Corn Exchange Road, Municipal Buildings, Stirling, http://www.britishlistedbuildings.co.uk., accessed on 10/04/2011.
[198] Walker, D., 1975, p. 247.
[199] Hume, John R., *The Industrial Archaeology of Glasgow,* Blackie, Glasgow and London, 1974, p. 229.

materials. His design submitted for the British Architect concrete design competition in 1909 signalled a direction towards Art Deco.[200]

When William Forrest Salmon died on 11th October 1911, the partnership was destabilised by his will in which his share of the business was not mentioned, leaving his second wife Agnes as a partner whose share of the business Salmon Jr could not afford to buy out and which Gillespie did not want, leading to the end of the partnership 18 months later, in 1913.[201] As Salmon Jr lost the family home in Kilmacolm, he moved into a flat in Blythswood Square where he set up his practice.[202] The split between the partners was amicable.[203]

Salmon Jr continued working on smaller projects for the Scottish National Council during the First World War, and carrying out mainly domestic and hospital work until his death in 1924. He also continued to pursue his architectural interests as the first editor of the RIAS journal established in 1922, and his interests in social reform and working class conditions.[204]

Gillespie employed the architect Jack Antonio Coia (1898-1981) in 1915, who also worked for other architects and then went to London, and made William Alexander Kidd (1879-1928) a partner in 1918. When Gillespie died in 1926, Kidd invited Coia to return to the practice; their partnership lasted until Kidd's death in 1928. Coia inherited the practice and continued it as Gillespie, Kidd and Coia.[205] The Modern Movement design approach was taken on and developed further by Isi Metzstein who joined the practice in 1945 and Andrew MacMillan who joined in 1954.[206] The work of the practice between 1958 and 1987 was a subject of the exhibition in The Lighthouse, Glasgow, in 2008, and a book.[207]

A century before that exhibition, the Lion Chambers was the first sign of the Modern Movement in Scotland that fully developed through the 20th century. In 1904-5, Salmon Jr and Gillespie worked on an innovative design for a new office building for William George Black, the client who was as brave as they were to experiment.

1.2.2 The Lion Chambers client

William George Black (1857–1932) was a respected and socially active Glaswegian. He was educated at the University of Glasgow and Gottingen in 1879. In 1884, he became a partner in his father's legal firm Black, Honeyman and Monteath. His interests included art and publishing on legal, archaeological and anthropological subjects. He was a member of the New, Art, and College Clubs, Glasgow; the University Club, Edinburgh; and the Royal Societies Club, London. His wife Anna Robertson was a daughter of Robert Blackie, of Blackie

200 Walker, D., 1975, p. 247.
201 O'Donnell, R., 2003, p. 49.
202 Ibidem, 54.
203 Ibidem, 129.
204 O'Donnell, R., Acquiring a Taste for Salmon, RIBA Journal, August 1990, p. 40.
205 Dictionary of Scottish Architects, Gillespie Kidd & Coia, http://www.scottisharchitects.org.uk, accessed on 20/04/2011.
206 Ibidem.
207 Gillespie, Kidd and Coia: Architecture 1958-1987, http://www.gillespiekiddandcoia.com, accessed on 20/04/2011.

& Sons publishers, and a niece of John Blackie (1805-1873)[208] who became Lord Provost of Glasgow in 1863 and initiated the City Improvement Scheme that transformed housing for the poor and the city’s infrastructure.[209]
Black was Deacon of the Trades House of Glasgow in 1916-17. For his work during the First World War, in Voluntary Aid Detachment committees, in helping disabled officers and in the post-war training of officers, he was made CBE. His public activities included being a governor of Baillie’s Institution, a member of council of the Regality Club and of the Master Court of the Weavers Incorporation, vice-chairman of St Mungo’s College and chairman of the Ophthalmic Institution of Glasgow. In 1930, he presented the Mercat Cross which stands in the Merchant City in Glasgow.[210]
As a member of the Glasgow Art Club, whose premises, designed by the architect John Keppie (1862-1945), also the club member, were at 185 Bath Street since 1893[211], Black could have met there not only the artists but also the architects who worked in Glasgow.
Black owned the building at 168 Hope Street at the corner with West Regent Street.[212] It stands diagonally opposite the house at the corner of 79 West Regent Street and 183-191 Hope Street, built in the mid 19th century and altered to offices, tearooms and a restaurant by Salmon, Son and Gillespie in 1903[213]. These alteration works would have been noticed by Black as well as Salmon Jr’s impressive tall building the ‘Hat-rack’ (1902) that can be seen while walking from Central Station up Hope Street, as it stands close to the corner with St Vincent’s Street. Black could have met Salmon Jr in Glasgow’s art circles, but was also able to see the originality and virtuosity of the ‘Hat-rack’ close to his offices. It is not then surprising that Black commissioned Salmon, Son and Gillespie to design the Lion Chambers in 1904.

[208] Eyre-Todd, G., *Who is Who in Glasgow in 1909,* Glasgow and London, 1909, p. 19, also available at http://gdl.cdlr.strath.ac.uk, accessed on 24/03/2011.
[209] MacLehose, J., (1886) *Memoirs and portraits of 100 Glasgow men,* http://gdl.cdlr.strath.ac.uk/, accessed on 24/03/2011.
[210] Fullarton, D. Arrochar couple’s gift to Glasgow, Helensburgh Heritage, http://www.helensburgh-heritage.co.uk, accessed on 24/03/2011.
[211] The Glasgow Art Club, History, http://glasgowartclub.co.uk, accessed on 24/03/2011.
[212] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 19th 1905. *Proposed Building Hope Street for Wm Geo Black Esq. Block Plan.* A copy of the original drawing. Four Acres Charitable Trust.
[213] Extract from Statutory List, Glasgow City Council, HB number 33258, Category B, http://www.glasgow.gov.uk, accessed on 23/03/2011.

2.1 **New trend in architecture in Italy at the turn of the 20th century and early *"Modern Architecture"* in Matera (Italy)**

The monolith[1] is *"an impenetrable object that does not directly communicate with the context or refer to anything but itself, which tautologically represents its own autonomy. It is akin to the architecture when it succeeds to conceal the plurality of its physical, functional and economic components, within the perfection of a unique form or a sign, or even gives to the uniqueness the sense that flows out from its own symbolic and figurative charge that highlights the existence of a common area of search between art and architecture."*[2]

Plate 2.1: Risorgimento bridge in Rome

The monolithic form directly refers to the individualisation of a pure volume, an object without ambiguity that brings a human creation into harmony with the universal order: as the mineral is forged from melted magma, the building originates from the flow of concrete (a freely mouldable artificial stone).

From the second half of the 19th century and, then, in the first decades of the 20th century, the progressive spread of the use of iron and reinforced concrete was assisted by the publication of construction acts that enabled the realisation of load-bearing structures through rational procedures that could be easily applied. In Italy and Europe, there are still interesting examples of constructions in which the technological and construction evolution can be observed on the architecture of those years.[3]

This research aims to contribute to the context of more general studies on the evolution of the architectural techniques and language typical for the buildings of the 20th century in the South of Italy and particularly in Basilicata. Its focus is on the "problematic" aspects of relevance to the advent, spread and evolution of the reinforced cement conglomerate techniques in Italy. As in the above part concerning the United Kingdom, there will be some reference to the Hennebique system (see Chapter V), introduced by

[1] The word monolith derives from Greek μονόλιθος (monólithos) and consists of μονός (monós), which means "single" and λίθος (lìthos), which means "stone".

[2] Stefano Averame, architect.

[3] Mattone, M., Amarilla L. *Architettura in ferro e calcestruzzo armato. N uove tecnologie costruttive tra Ottocento e Novecento in Italia e in Argentina,* CELID 2011.

the company G. A. Porcheddu from the end of 19th century and in the first decades of the 20th century. To give an idea of the activities undertaken by the Porcheddu firm in Italy, it should be mentioned that it delivered over 2,600 executed and documented works. Among the company's most important realisations, some of international significance, are the Risorgimento bridge in Rome[4] (Plate 2.1), which holds the world record as an arched bridge in reinforced concrete with the largest span, and the Fiat Lingotto factory in Torino (Plate 2.2) which attracted interest of contemporary critics.

In addition, this new construction system had the advantage of simpler execution in relation to the traditional construction (for example, the overlapping of some works, the optimisation of the use of labour, etc). An economic advantage of the use of this construction technique also emerged from these aspects.

The spread of the use of the reinforced concrete

The arrival of the reinforced concrete in Italy was also contemporary with the phenomenon of industrial expansion: in fact, in the last years of the 19th century the market began demanding new factories of a certain size and new residential areas associated with them. Other realities, such as the level of development in the South of Italy, saw the evolution of the reinforced concrete essentially dictated by the advent of building Purchasers and Companies from the North of Italy (Plate 2.3) and by the "speed" of construction associated to a greater and an obvious "flexibility of dimensional typology".

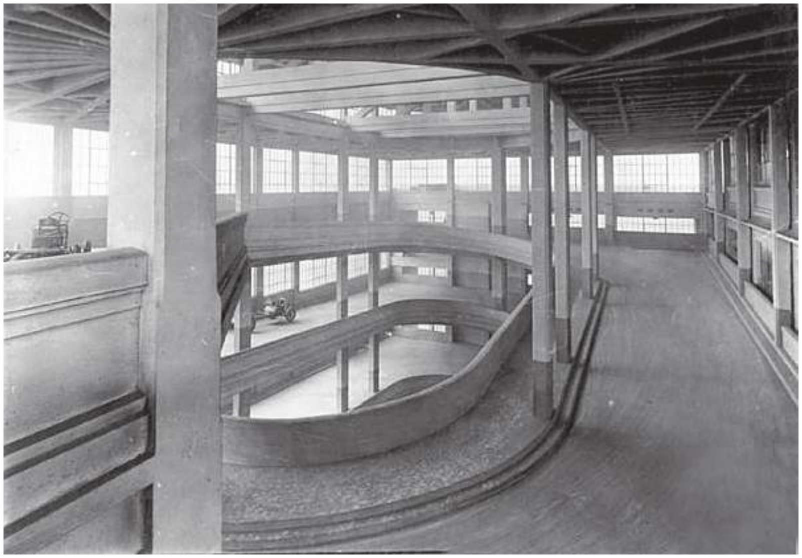


Plate 2.2: Fiat's Lingotto in Torino, helicoidal ramp, 1927

In Italy, after the First World War, a slow and static resumption of the development of architectural knowledge followed, which, if looking at the theory or handbooks, remained full of gaps, and from the practical point of view seemed even more evidently "deaf" to the transformations and innovations noticeable in other parts of Europe. The theoretical and practical endavours were more directed towards contribution to urban theories and concepts to the detriment of an architecture conceived as elaboration of structural elements that unite functional relationships with the building performance. In reality, while in Europe the acknowledgement of the innovations in the theory of construction represented a premise for the use of new materials, among which the reinforced concrete stood out, in Italy, in the first three decades of the 20th century, the new theoretical elaborations were simply limited to timid statements in various manuals, inserted

[4] The construction works on the bridge started in 1909 and were completed two years later. It was designed by François Hennebique for the exhibition that celebrated fifty years of the Italian union.

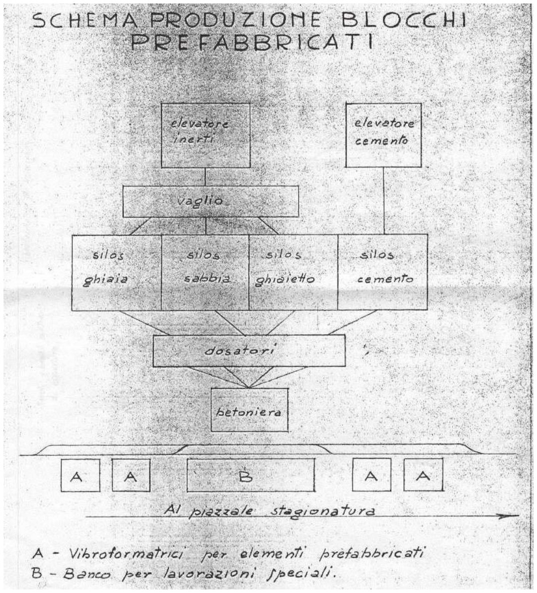
Plates 2.3: Historical images of building sites (Images from the private archive of Giuseppe Buonsanti, Matera)

in design phase without – almost – any practical confirmation in the construction phase of the works.

The failed resumption of building activity immediately after the First World War shows the continuation of an operational condition that will slowly change the technical heritage acquired in the years around the turn of the century, which will only later be enlarged and modified thanks to the usage of new machinery and manufacturing: the embelishments and decorations were simplified and gave place to stone or ceramics, the more simplified implementation, the thickness of walls was reduced to be less of load-bearing function, and new brick elements that were made lighter through the process of extraction.

The technical literature of 1920's and 1930's in

Plates 2.4: Usage of prefabricated components (a) and design plans (b) - Image from the private archive of Giuseppe Buonsanti, Matera)



Italy did not succeed to grasp comprehensively the significance of these transformations; in fact, the main themes of the textbooks of the end of the 19th century were proposed again (because of their acknowledged validity) with limited updates related only to the new construction techniques and the applications of reinforced concrete. Some manuals, also looking with enthusiasm at the prefabrications in reinforced concrete (Plate 2.4), considered the reinforced concrete in the same way as other structural components and limited its application to the substitution of building parts, making difficult the process of recognition of the real revolutionary possibilities in the use of this material.

In Europe, however, the cultural debate was marked by an atmosphere of great renewal; in their manifests, the schools and personalities who spoke to define the sense of "new architecture" stretched to negate the traditional construction technologies in favour of the new ones. In Italy, on the contrary, the innovative applications in housing and public buildings had a completely marginal role because they were only used to substitute the more traditional components: many years will pass before the new technologies were introduced on a large scale.

Initially, the use of concrete spread thanks to the realisation of large hydroelectric projects. Ludovico Quarony[5] commented on this: *"As the birth of reinforced concrete was not helped by manuals comparable to those that accompanied the rise of iron, in reality the research and experiments on the possibilities of the material took place within the construction institutes with all the advantages of pure, specialised scientific research, but with all the difficulties related to the lack of cultural collaboration with the architecture."*

The Basilicata in 1900's

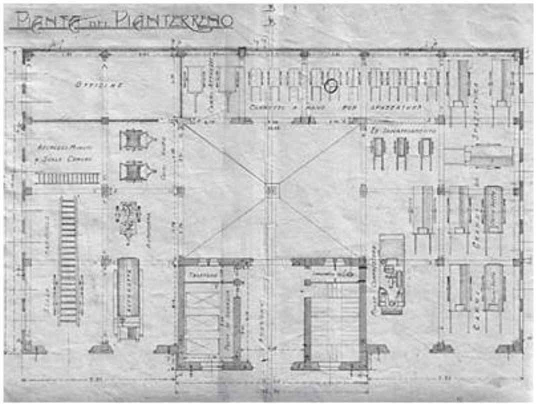
Considering numerous existing publications and studies[6], this publication, regarding the Italian situation, will provide only a summary of the evolution of the construction techniques of the reinforced concrete in order to focus on the architectural reality of the South of Italy and on the building developments at the start of the 20th century in Basilicata, between tradition and innovation.

The research objective, therefore, is to deal with the theme or restoration and evaluation of areas strongly marked by experiments in construction techniques of Modern architecture in the territory of Basilicata. The research motivation was the presence, in the regional area, of a heritage that consists of modest settlement complexes, and the emergence of specialized architecture, characterised by the experiments with the modern construction techniques or by new building techniques with traditional materials, little known and not studied and evaluated.

The first half of the last century represented a significant moment for the Italian architecture due to the creative architectural experiments and the application of modern urban principals, marked by the use of new materials or technologies and linked to particular social, political and economic conditions following the

[5] Ludovico Quaroni (Roma, 1911 - Roma, 1987) was an esteemed Italian urbanist and architect.
[6] Nelva R., Signorelli B., *Avvento ed evoluzione del calcestruzzo armato in Italia: il sistema Hennebique,* AITEC (Associazione Italiana Tecnico Economica del Cemento), Ed. Scienza e Tecnica, Milano, 1990.

Plates 2.5: Former Firefighters' station - Potenza 1929



wars and the need for reconstruction. The built heritage of Basilicata is strongly influenced by the experiments of "Modern" architecture and by the extraordinary activities of the Reclamation and Land Reform (in 1950's) which have significantly contributed to the development of the architecture in the 20th century.
The builders involved (often with an immediate task) in this process had also the valuable contribution of numerous designers, already acclaimed or "future masters" of the contemporary engineering, urbanism and architecture from all parts of Italy who developed new organisational schemes, new forms of settlements, of their relationships and use, starting from the large engineering solutions for hydrogeological problems, to the definition of proper and adequate hosing models within the settlement planning specifications.
Among the architectural works of the first three decades of the last century there are many public buildings, including barracks; among them the former Firefighters' station in Potenza (Plate 2.5) is a particularly interesting object for research due to its innovative character regarding local construction methods of that era. Since its construction in 1929 the building has lost its original form, distorting the building connotation by almost concealing its load-bearing structural frame in reinforced concrete; this was one of the first crucial examples of the construction technique that was rearly used locally, from which rose a pioneering company of Ravenna (Cooperativa Muratori e Cementisti).
One can see, for the first time here, the more appreciative local builders adopting an innovative model in which the use of reinforced concrete frames and the application of light slabs in the lofts will become, within still traditional construction methodology of Basilicata, building standards destined for a wide range of building applications in decades to come.
The cognitive phase of identification and classification of construction technologies and techniques has seen a collection of national standards and technical references before any local ones. The introduction of legislative acts has, in fact, modified the technical ones as well as the use of construction materials; thus, it has restructured the standards by deepening those that brought the innovations into the established tradition.
An interesting research find were two technical publications of 1947 and 1948 that describe

the use of the SAP[7] (Senza Armatura Provvisoria – without provisional reinforcement), one of the most important innovations of the era. The spread of this type of slab and its multiple variants enabled, above all, faster construction due to the possibility to put together the tubular beams on site.
The research that was undertaken has established that the building production at the start of the 20th century was affected by an innovative, almost continuous process, firstly, in the use of new materials such as cementous binding mediums, construction steel, and then the more complex construction techniques that accelerated the execution. The interventions in 1953 related to the construction of public buildings (Plate 2.6) and farmhouses in Scanzano and Policoro (Matera, Italy), acknowledged the innovations of the standards related to the prefabrication and the organisation of building site.
For this reason, the restoration and the evaluation of this considerable heritage, which is fragmented and strongly marked by the experiments in construction techniques of the Modern architecture, have to include the awareness of how it was built by using the traditional and modern construction techniques, and additionally, of the relationship between the traditional and modern materials with the new construction methods, little known and not at all studied and evaluated.
In the first years of the 20th century, due to the reduction of the craft manufacture of local and many historical materials (stone, wood, iron), the projects that "dictate" the use of modern techniques and materials were undertaken nationally.

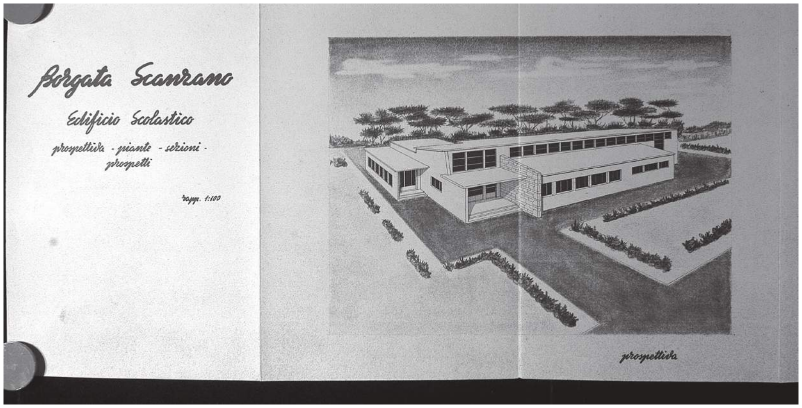


Plate 2.6: Project for the school Borgata di Scanzano (Matera, Italy), 1953

2.2 **Ludovico Quaroni, Carlo Aymonino, Giancarlo De Carlo and Ettore Stella**

In the middle of the 20th century, the cultural and architectural enthusiasm that marked the economic boom following the post-war reconstruction can be noticed in Basilicata through the actions better known as the "Land Reform"[8] and depopulation of the "Rioni Sassi" (Rock Quarters) in Matera. Palmiro Togliatti in 1948 and then Alcide De Gasperi in 1952 visited the town, and De Gasperi signed the frist Specail Law for the evacuation of the Sassi in 1954.
The two thirds of all the inhabitants of the town were forced to abandon their homes and move to new quarters following the State decision.

[7] In 1920's, the top mixed roof slabs consisted of rods placed in concrete between hollow bricks and finished off with a thin, upper cementous slab. Gradually, one could see the introduction of the slabs in concrete and reinforced hollow bricks where the upper slab was substituted, for static effects, by brick ribs. The provisional reinforcement on the latter type of slab had to be reduced. This requirement was met by the SAP slab without provisional reinforcements, consisting of many tubular beams made of hollow bricks and put together on site. At the moment of construction the beams are placed in position closely to each other.
[8] Giura Longo R., Movimento contadino, classe politica ed intellettuale nel secondo dopoguerra: Mezzogiorno e Basilicata in "Dall'occupazione delle terre alla riforma agraria", Basilicata Regione Notizie, n. 3/1999, XXIV, Consiglio Regionale di Basilicata, pp. 25-34.

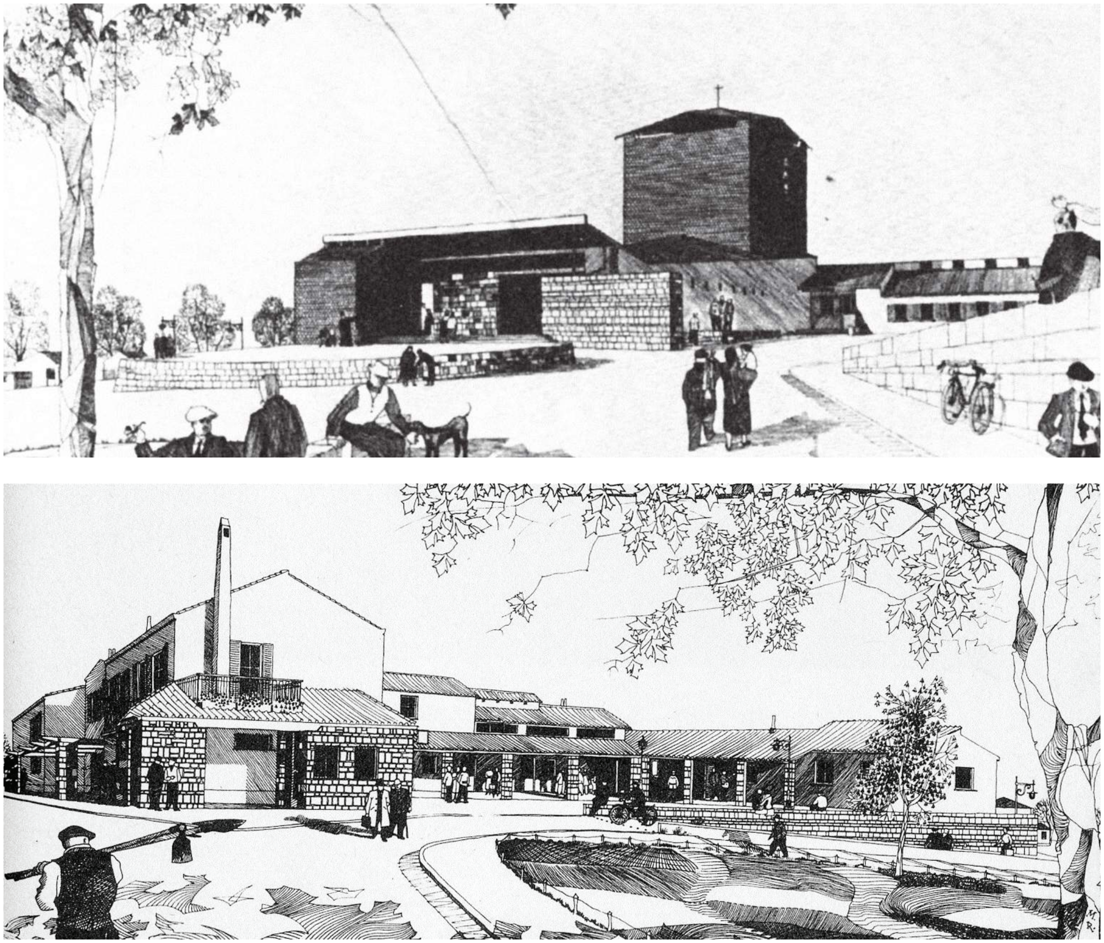


Plate 2.7: The rural village La Martella, Matera (Image from "La città Fisica, L. Quaroni, Laterza, Bari, 1981")

The greatest sociologists, anthropologists, architects and urbanists of the era were invited to design the new town quarters to accommodate 15,000 evacuated people.

Three rural villages were built (*La Martella, Venusio and Picciano*) to house the families of agricultural labourers close to the fields on which they worked. Other urban quarters were built, in full respect of the Regulation Plan of 1956 signed by L. Piccinato (Legnago, 1899 - Roma, 1983).

Important figures such as Ludovico Quaroni, Luigi Piccinato, Carlo Aymonino (Roma, 1926 - Roma, 2010), Plinio Marconi, (Verona, 1893 - Roma, 1974) and other minor ones contribu-

[9] UNRRA-CASAS - United Nations Recovery Rehabilitation Administration (Comitato Assistenza ai Senzatetto).

[10] Italian businessman, engineer and politician; a great and remarkable personality of the era after the Second World War (Ivrea, 1901 – Aigle, Switzerland, 1960).

ted to the research and development of new settlement models for these new villages. The real support of the Reform Body will be often combanied with the activities of UNRRA-CASAS[9] and the Fund of the South of Italy (Cassa del Mezzogiorno), as was the case for the interventions realised in Matera following the law on Redevelopment of the Rioni Sassi. In the years following the evacuation of the Sassi quarters, the town of Matera became an authentic laboratory; the Commission for the Study of the Town and Countryside of Matera was born, promoted by UNRRA-CASAS and established by Adriano Olivetti[10], the president of the National Institute of Urbanism and by the sociologist Frederick Friedmann, assited by experts in diverse disciplines such as history, demography, economy, urbanism, paleonthology, sociology, to design and create quarters that will continue, in the best possible way, the social life of the Sassi.

"New places" such as La Martella, Borgo Venusio, Borgo Taccone, Scanzano, Metaponto, and Borgo Irsina belong to this historical and

QUARTIERE SERRA VENERDI'

- superficie totale del quartiere		mq.	148.686
- superficie coperta delle costruzioni		mq.	28.000
- consistenza del quartiere:	fabbricati	N.	62
	alloggi	N.	828
	vani legali	N.	4.320
	negozi	N.	37

Il quartiere è servito da:

mq. 64.900 di strade
ml. 8.000 di fogna
ml. 7.000 di acquedotto

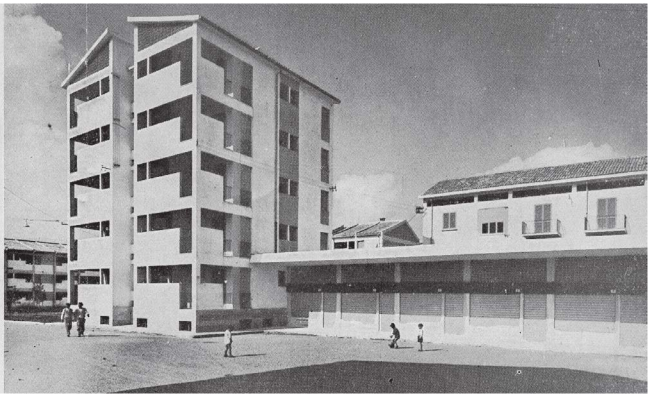


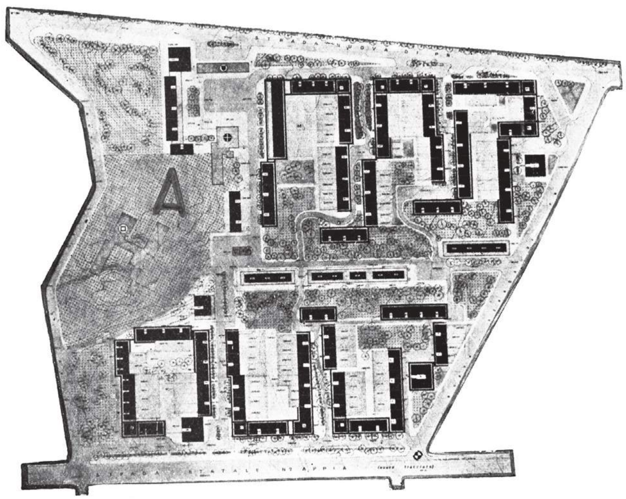
Plate 2.8: Quarter Serra Venerdì, Matera 1954

cultural context, to mention only a few in the territory of Basilicata.

The Borgo La Martella (Plate 2.7) rises at a few kilometers distance from the town. After the first proposal by the Materan architect Ettore Stella, interrupted by his early passing, the project was entrusted to the office of the Roman architect Ludovico Quaroni; the village church, also designed by Quaroni, is of great interest.

The Quarter Serra Venerdì (Plate 2.8), chronologically the first one, was designed, as the Quarter Platani, by the architect Luigi Piccinato who was also the author of the first General Regulation Plan of the town.

The Quarter Spine Bianche (Plate 2.9), as the previous village, is a work of great importance by the contemporary Neorealist of the Italian Rationalism; it was designed by the group led by



QUARTIERE SPINE BIANCHE

- superficie totale del quartiere . . .		mq.	54.951
- superficie coperta delle costruzioni . .		mq.	10.800
- consistenza del quartiere:	fabbricati .	N.	14
	alloggi . .	N.	323
	vani legali .	N.	1.880
	negozi . .	N.	14

Il quartiere è servito da:

mq. 20.800 di strade
ml. 4.200 di fogna
ml. 1.480 di acquedotto

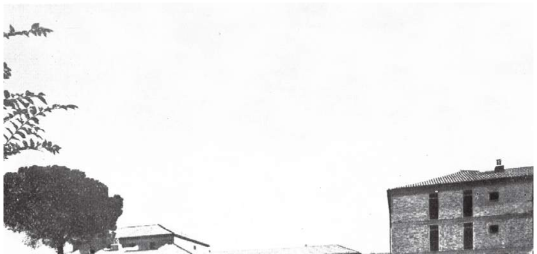


Plate 2.9: Quarter Spine Bianche, Matera 1955-59

- superficie totale del quartiere		mq.	93.927
- superficie coperta delle costruzioni		mq.	10.959
- consistenza del quartiere:	fabbricati	N.	30
	alloggi	N.	333
	vani legali	N.	1.701
	negozi	N.	19

Il quartiere è servito da:

mq.	28.200	di strade
ml.	4.230	di fogna
ml.	1.028	di acquedotto

Con l'assegnazione degli alloggi di questo quartiere, completato di recente, le famiglie trasferite dai «Sassi» raggiungono il numero di 1.411.

Plate 2.10: QuarterLanera, Matera 1955-59

the architect Carlo Aymonino. Some buildings such as Casa di Matera, which faces the church square, were designed by the architect Giancarlo De Carlo. Also named "Bottiglione" (from the name of the construction company), the quarter was entirely built in brickwork with the external contours of extraordinary simplicity. The Parish Church dedicated to San Pio X, the services and a few schools rise in its centre.
The Quarter Lanera (Plate 2.10), at the elevated position on one of the highest hills of the town along the western bypass and in the vicinity of the castle hill, was designed by the engineer Marcello Fabbri and the architect Coppa.

2.2.1 The work of Ettore Stella[11]

At the end of 1940's, as the war was over, local professionals came back to Matera, after graduating in big cities (where they could learn

[11] Ettore Stella, (Matera, 1915 - Altamura, 1951), architect and urbanist. Graduated at the Regia Scuola Superiore di Architettura (later transformed into the Faculty of Architecture) in Rome.

about the new directions in architecture and urbanism), and decided to apply their intellectual and professional energy to affirm, in their own town, the new principles of modernity and good architecture.

The presence of these professionals, among whom the young Ettore Stella stood out, led to the first sensible transformations of the town, which contained a series of "fermenting" spaces that drove its slow and gradual evolution. At that time, the above mentioned community actions by Adriano Olivetti and UNRRA CASAS started. The town, in fact, opened to the contributions of external scholars: sociologists, urbanists, geographers, historians, assembled in Matera and co-operating with local contacts, including the young Stella. Stella, educated at the School of Architecture in Rome, after having met the best Roman architects, decided to return to Matera, his birthplace, to complete what he defined as a civilizing mission. In only four years of his "mission", as he died when he was only 36 years old in 1951, Stella produced projects and works which definitely signaled the urban and architectural evolution of the town. The young man, gifted with a creative and original talent, quickly came to the attention of the architects and specialized critics of the era, becoming the winner, as a student, of the National Competition for architectural students, together with Emilio Stefano Garau. His project for the Auditorium of 5,000 seats with the G.U.F. (Gruppo Universitario Fascista) Palace for the International Exhibition in Roma in 1942 (E. '42) was highly praised by the architect Giuseppe Pagano (Parenzo, 1896 – Melk, 1945) on the pages of Casabella. *"In the orgy of columns"* and *"fake arches"* of E '42, the winning project was honoured for its structural clarity. The *"moral lesson given by the two young students of the Roman school should make the director blush",* concluded Pagano.

During and after the studying in Rome, Stella was frequently in the studio of the architects Amedeo Luccichenti and Vincenzo Monaco, with whom he often collaborated, alternating intense activity with the battles of the modern architecture against prejudices of the monumentalism that was typical of Piacentini.

A. Restucci[12] wrote: *"Those were the heroic years in which the magazines such as "Comunità", "Metron", "Domus" – edited by Rogers from 1946 to 1947 – or "La Città Nuova"edited by Michelucci from 1945, inheriting with articulated views Pagano's proposals in "Casabella", widened the investigation areas of the critical analysis by suggesting a "rereading" of the historical heritage of the modern movement. These are the same themes of Stella's proposal to formulate a new language also in Matera."*

He is one of more remarkable figures in the panorama of the Organic Rationalism after the Second World War in Italy and Basilicata.

"This is the language that Stella had assimilated in the debates in the Roman school where he understood the aspirations of the architecture to reunite with the technological innovations in the post-war era. The rest was the faith in a new architecture capable of influencing the image of the town with the clarity of a formal and technological message, marking Stella's projects that show a fidelity to rigorousness of the Italian pre-war research." (A. Restucci).

Riccardo Musatti[13] wrote in *"Metron"* that Stella had initiated in Matera *"a pioneering, civilizing mission of the modern architecture in the town whose urbanism was the most backward in Italy".*

[12] Architect, Full Professor SSD ICAR/18, Honorary Rector of the I.U.A., Venezia, Italy, from 2009.
[13] Riccardo Musatti, born in Rome in 1920, journalist and sociolog. Co-editor of "Metron-Architettura"

In fact, he began the early debates on the redevelopment of the Sassi and, in 1946, prepared an interesting documentary dossier on the harsh reality of the Sassi of Matera, directing the politicians towards an appropriate expansion of the town. Stella anticipated the attention that the American and Italian sociologists, economists and architects will give to Matera.
In Matera, at the and of 1940's, he completed works of great architectural and structural value such as the Duni Theatre (see Chapter IV), a rare example of modern architecture, the Anti-tuberculosis Sanatorium (Plate 2.11, b) and various buildings for public housing.
In the area of the interior architecture, he designed amazing and original pieces of furniture in shops such as "Libreria Montemurro" (Plate 2.13) in Matera and the "Gran Caffè Italia" (Plate 2.12) in Potenza and in various private residences.

In 1950, he was invited by Adriano Olivetti to establish the first working group for the inauguration of the Commission for Studies on the Town of Matera together with the engineer Gian Battista Martoglio, leading to the design of two hundred flats for homeless of Matera in locality "Timmari – La Martella"; the project was never realised (although approved) and remained in the drawers of UNRRA – CASAS.
In February 1951, the architect Stella died suddenly and tragically in a road accident, at the age of thirty five, ending his promising professional career. The project was interrupted and reworked by a group of professionals led by Ludovico Quaroni. Among all, at least two works, one private and one public, immediately received a vast response and interest of the national architectural culture: the *Cine-Theatre Duni* and the *Anti-tuberculosis Sanatorium*.

Plate 2.11: The vestibule of the Duni Theatre (a - Image from the private archive of Dr Angela Montemurro, Matera, foto Vasari, 1949, Roma) and the Anti-tuberculosis Sanatorium – Detail of the stairs (b - Image from the private archive of "commendatore" Michele Ficarelli, Bari).

Plate 2.12: Interior and chair for the "Gran Caffè Italia" (Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

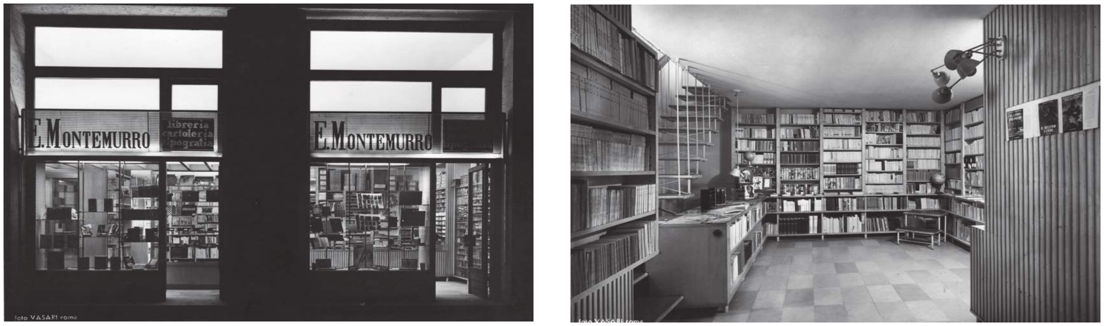


Plate 2.13: Shop window and interior of the "Libreria Montemurro" (Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

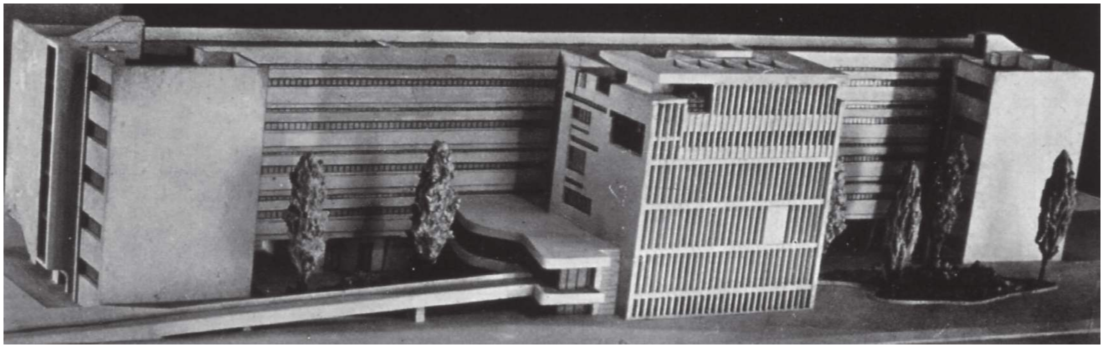
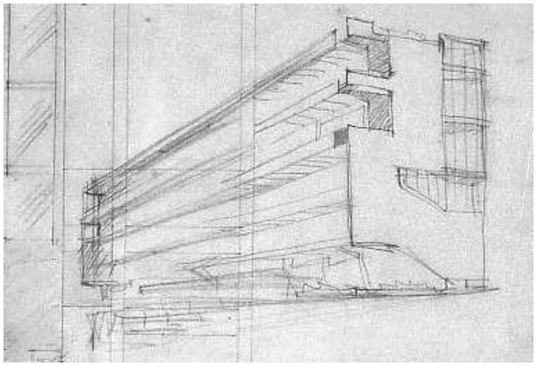


Plate 2.14: Model of the Anti-tuberculosis Sanatorium partially realised.

The Cinema Theatre was commissioned by a few citizens who understood the need for culture in the town and demonstrated an active civic spirit. Stella, thus, produced the first high quality modern work in Matera; the first to have been entirely built in reinforced concrete. The project for the Sanatorium Ward, within a general hospital complex, for which Stella was responsible, was marked by complications and delays, and was not completed during the architect's life. Notwithstanding other events, the project (Plate 2.14) of great force and modernity was presented and praised at the Reconstruction Exhibition in Rome.

The building project was developed through a long research on architectural form, documented by numerous hand sketches (Plate 2.15), before the final project was drafted.
The new architectural language introduced by Stella initiated the renewal of construction techniques in Matera and started a new era that opened the town to further significant contributions in subsequent years. Stella's modernity resides in the trust that he had in the civilisatory effects of modern culture, in the expressive possibilities of new, industrially produced materials and in the eagerness to create a more civilized place through the architecture.



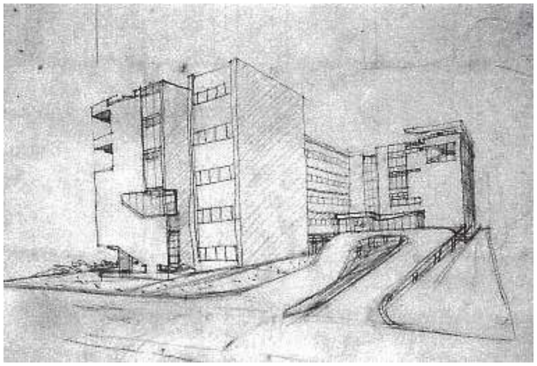


Plate 2.15: Stella's hand sketches (a) axonometry of the front view and (b) axonometry of the rear view

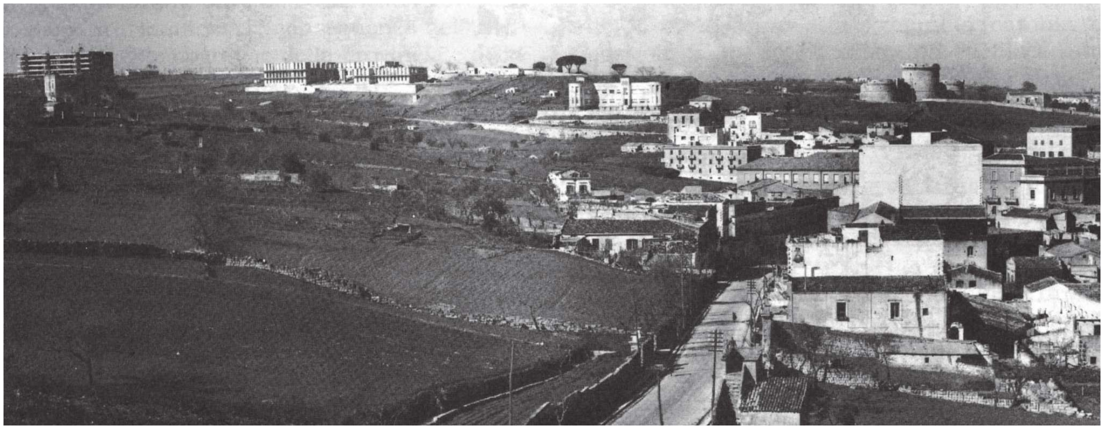


Plate 2.15: Hystorical image from 1950's: view of the hill from Via Lucana and the abandoned Sanatorium

Plate 2.16: Actual front view

Plate 2.17: Pavilion by Corazza

The Sanatorium was built on a hill, south-west of the historical centre, because of the sanitary characteristics of the location. In fact, a few years before, following Mussolini's order, a Heliotherapeutic Collony was built on the same hill. In 1946, the architect Emanuele Plasmati completed the "Regulation plan for the inner town and the expansion" and identified the hill with the Castle and the Heliotherapeutic Collony as an area designated for an urban park.

In the same year, with a view on revival and renewal, the Town's Interim Administrator (Commissario Prefettizio), decided that a series of public buildings should be built. The job was given to three young architects: Plasmati, and the associates Stella and Masciandaro. Plasmati was given the task to design an *Orphanige for boys and girls with an annex for abandoned children.* The project for the *Provincial lunatic asylum and the Hospital with a pavilion annex for the Provincial Anti-tuberculosis Sanatorium* was entrusted to Stella and Masciandaro. The area in which the buildings were to be located was the urban park which already contained the Castle and the Heliotherapeutic Collony. Only the *Anti-tuberculosis Sanatorium* received funding and was to be built secluded on the hill, accommodating around 150 beds.

In 1948, the works started and continued until the completion of the structure, and then stopped for a year due to problems of economic and construction nature, while the building fell into a "sate of complete abandon" as documented by Stella's letter to the Provincial Anti-tuberculosis Consortium (Plate 2.16). In 1951 Stella died, and his Roman masters Amedeo Luccichenti and Vincenzo Monaco offered to complete the work "according to the criteria of the deceased" and to designate their fees for a scholarship in architecture that would be given to a young person from Matera. Thus, in 1951, the architectural direction was entrusted to them, while other services were entrusted to the Technical Office of the Province. As the collaboration was not efficient, the work was entrusted to Masciandaro. The construction resumed with difficulty but was again stopped in 1956. The Provincial Anti-tuberculosis Consortium decided to sell the constructed part of the building, but without success.

Similar unfortunate events accompanied the construction of the Orphanige whose project was entrusted to Plasmati; in order to be completed, the building was transformed into Public Hospital. In 1959, the Sanatorium was still unfinished and the Provintial Anti-tuberculosis Consortium gave the three upper floors of the building to the Public Hospital that completed the construction. In 1961, the Public Hospital was opened, consisting of the structures that were planned for the Orphanige and the Sanatorium. The built Sanatorium (Plate 2.16) shows considerable differences in relation to Stella's design proposal as clearly demonstrated by the sketches and the model. The ground floor is closed in a volume which Stalle had not envisaged; the rear view got an additional volume on the first floor instead of the ramp conceived by the architect; the windows of the rear view, planned as a ribbon were substituted by sliding windows.

In 1970, the competition for the new Public Hospital in Matera was announced and won by Corazza, Masella and Baldoni; this project was never realised and, in 1979, the task of designing the extension of the existing hospital was entrusted to Corazza (Plate 2.17). The project consists of a pavilion adjacent to Stella's pavilion, linked by a corridor at the third floor and another one at the ground floor. The building is the first example of a prefabricated structure in health buildings.

3.1 **A *"critical"* approach to building restoration**

The conservation intervention on a historic building, regardless of its architectural and/or artistic value, is generally more appropriate if information on its construction, evolution to date, materials, construction techniques and structure is available. The conservation of built heritage highlights different issues such as the vast number of buildings needing attention and the urgency of cases that have to be resolved with limited economic resources and time. To undertake a suitable intervention, three questions have to be answered: whether, where and how to restore. The fourth question could be added, in which the economic aspect dominates: when to restore. To be able to respond adequately to these questions, it is necessary to proceed by developing specifications step by step, starting from a detailed knowledge of the entire building, the level and causes of degradation, and by finishing with the "operational" description of the proposed interventions.

Within the preliminary data acquisition phase, the direct survey of the building characteristics and condition, and the mapping of any noticed changes are accompanied by the research on the project documentation and the events that have affected the structure during its construction and throughout the building life. Then, very precise design and operational directions need to be developed to support decision making on possible interventions and to plan the restoration of built heritage as a system in which technical and cultural variables create a balance between decisions and processes of conservation and transformation. In other words, instead of a generic and generalised model of development, which applies the same parameters in a literal and an indistinctive manner to all buildings, a more "flexible" approach is required, capable of interpreting the unique character of buildings in an area.

The current approach to the restoration is profoundly silent on how the built heritage could be transformed from a "burden" to a society to the primary resource for a compatible and balanced spatial development. This new perspective defines restoration as "a cultural act" (based on historical, scientific and technical evidence), understood in its widest sense as an "integrated restoration" that is open to the potential use and reuse, and to the material, technological, urban, spatial, ecological and environmental requirements.

It seems generally difficult to achieve environmental quality in traditional architecture through prescriptive and constraining approaches. These approaches, often coupled with normative models which translate living conditions into objective parameters and standards, hinder the interventions such as a "simple" maintenance or a restoration, or produce the result that is not logically related to the struc-

tural, typological, functional and technological characteristics of the artefacts.
An "appropriate" restoration should plan the reuse of built heritage and aim to achieve building performance comparable to new buildings. The reuse interventions should be integrated with the conservation and not imposed. They should not cancel "historical layers", understood as the complex of values acquired through time. The above premises form the foundation of a "global" methodological approach whose objective is to define performance requirements which will enable the selection of adequate intervention actions.
Therefore, the first phase of this approach could consist of identification of the technical and technological options that meet the performance required from the building and the whole context of traditional architecture that will enable the transformation while preserving the character of built heritage. The second phase could define the criteria and methods for an appropriate intervention by assessing the compatibility of identified options and a building.
Realising an intervention by applying the methods developed through this "global" approach enables determining a "well-balanced" attribution of the historical, functional, economic, technical and other values which can sometimes have conflicting aims. This approach assists in achieving a quality of restoration with a substantially increased level of process control and respect for the original character. The above methodology highlights how the approach could be helpful for the classification of pathological events within a building and for the application of innovative solutions to increase the durability of restoration interventions.

3.2 The *"project"* of diagnostic investigations

The technological innovations assist in setting up very advanced technical investigations of building pathologies. They can indicate the principal characteristics of materials and technological and/or structural systems of buildings, enabling the preparation of a real and detailed diagnostic description. Various techniques are used to gain complete understanding of building pathologies. However, data on their applicability is still rather heterogeneous and not comprehensively systemised and documented. It should be noted that the methods for a "critical" survey of building pathologies could be[1]:

Non-destructive tests: That is to say the tests undertaken directly on the object without causing any damage (these tests do not really require any material survey) and without compromising its functionality. They can be undertaken directly on a structure. The limit of this investigation methodology is related to the results that could be obtained which, in general, provide only qualitative but not quantitative and/or numerical indications.

Destructive tests: These are all investigations undertaken directly on the object by taking out samples of material that will usually be analysed in a laboratory. They provide precise quantitative results of the material condition and characteristics, although localised, i.e. related only to the parts from which the samples have been taken. The limit of this methodology is related to the specificity of provided information which is not always explicit with regard to the condition of the whole building.

[1] Pucinotti R., De Lorenzo R. A., *Non destructive in Situ Testing for the Seismic Damageability Assessment of "Ancient" R/C Structures,* Proceedings of III International Conference on NDT, Crete, Greece, 2003, pp.185-197.

However, it should be remembered that many of these techniques could be combined to enable the collection of data which is qualitatively and quantitatively correct and pertinent to the whole building. This approach is useful both for the classification of building pathologies of interest to the building and for the application of innovative solutions that will ensure durability of the restoration interventions.

3.3 **The investigative techniques for concrete**

The investigative techniques for concrete are also classified in two defined macro-categories ("destructive" and "non-destructive").[2] The former are based on the extraction of concrete samples to undertake compressive tests and represent the most reliable instrument for assessing the mechanical properties of concrete. They are regulated[3] by the European standards UNI 6131:2002, UNI 6134:1972, UNI EN 12504-1 2002.

The second investigative typology, the non-destructive tests, can be further subdivided in: really "non-destructive" investigations and "partially destructive" investigations. The latter include: (a) the penetration test with a Windsor gun (ASTM C 83) which enables the identification of compressive resistance of concrete by measuring the depth of penetration of the special metal pins projected with a Windsor gun into concrete, (b) the extraction test (pull-out) (UNI 10157:1992-ASTM C 900-06) which enables the assessment of compressive resistance of concrete by measuring the force used by a hydraulic jack for extracting a special plug inserted into concrete.

The really non-destructive investigations include, among others: (a) endoscopy that enables a direct observation of form and appearance of an investigated object, (b) thermography that assists in recognising potential structural anomalies by using the capacity of materials to transfer heat; (c) magnetometry which enables localising metal bars in reinforced concrete; (d) measurement of the electric potential of concrete which enables defining the level of corrosion of metal reinforcements in concrete; (e) ultrasound investigation that allows qualitative assessment of the concrete resistance by using the capacity of the concrete components to transfer ultrasound waves; (f) sclerometric tests that assess the concrete resistance by reading the bounce results, and finally, (g) so called "SonReb" (SONic + REBound) that enables assessing the concrete resistance by combining the speed of ultrasound waves and the index of surface bounce through a synergic use of the two previous investigations.

3.4 **The *"SonReb"* method for determining the resistance of concrete**

The SonReb method, as mentioned in the previous paragraph, allows a qualitative determination of the concrete resistance[4] through the cross-examination of the values of the speed of ultrasound waves and the values of sclerome-

[2] Ibidem, pp. 192-202.
[3] http://www.netconcrete.info/Calcestruzzo-normativa-tecnica.php.
[4] RILEM Draft Recommendation, 43-CND. Combined non-destructive testing of concrete. Draft recommendation for in situ concrete strength determination by combined non-destructive methods. Materials and Structures n. 26, 1993, pp.37-52.

tric bounce. This investigation method is standardised by RILEM Recommendations[5] 43 CND - EN 13791:2007, the EC regulation 1-2010 UNI EN 12504-2:2001, ASTM C597, UNI EN 12504-4:2005, the Test Report CUR 69, the standards UNI 7997, UNI 9524 and UNI 83308. Before providing an analytical description of the above method, a brief synthesis on the use of the ultrasound and sclerometric tests is outlined, presenting their functions, limits and advantages.

3.4.1 The sclerometric test

The test procedure is standardised by EC 1-2010 UNI EN 12504-2:2001. It is based on the use of a sclerometer (Plate 3.1), an instrument consisting of a power hammer linked to a spring whose release triggers a steel gun in contact with the surface of concrete. The bounce distance of the gun's steel hammer provides the bounce index S that can be related to the resistance of concrete through the instrument's specific curves. They take into consideration a potential inclination of the instrument in relation to the tested surface.

The test consists of carrying out at least nine readings[6] on a grid whose points have to be placed on a distance between 25 and 50 mm and at least 25 mm from the edge. The bounce index S for each test point is equal to the average of single values measured within the interval of 0.8 Im ÷ 1.2 Im, where Im is the average of all the measurements related to the investigated area.

Plate 3.1: Sclerometer for concrete, Model Boviar GEI

The interpretation of the obtained values is made through a graph that provides the bounce index values determined by the instrument on the abscissa axis and the compression resistance of material on the ordinate axis (Plate 3.2).

The results are closely connected to the type of analysed concrete: the low-strength and low-resistance concrete absorbs more energy in collision and therefore returns a lower bounce index value in relation to the one provided when the investigation is carried out on a stronger and more resistant concrete. However, there is frequently a case in which two concrete components with different characteristics have the same resistance but different strength; in terms

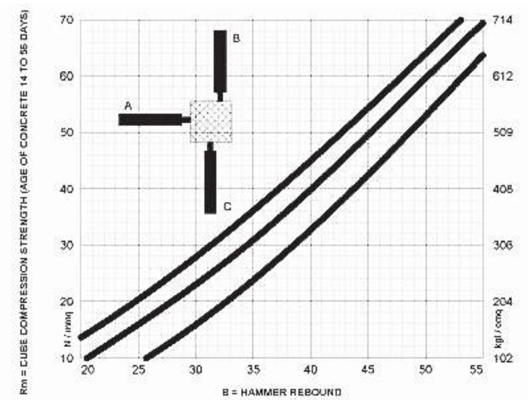


Plate 3.2: Table provided by the manufacturer that associates the bounce index S with the compression resistance of concrete

[5] RILEM (The International Union of Testing and Research Laboratories for Materials and Structures) is an organisation which enables exchanges through an international network of testing engineers, researchers, academics, educators and practitioners.

[6] See Standard UNI EN 12504-2: Tests on structural concrete – Non-destructive tests – Determination of the sclerometric index.

Plate 3.3: Equipment for ultrasound tests, type Boviar Ultrasonic DSP

of values, two different bounce indexes are returned, even at equal resistance. But, if two concrete components have the same bounce index, but different resistance, it can be verified whether the strength of the less resistant one is higher than of the more resistant one. However, because this investigation methodology involves only the surface of concrete, the result cannot be representative of the internal condition of concrete, but only of its surface condition. In fact, the surface carbonation of concrete, which increases the strength, can have higher sclerometric index values from those within the internal part of an investigated concrete structure.[7]
Further test limitations derive from its operation. In fact, the bounce distance depends on the kinetic energy of the battered mass before the impact and on the quantity of energy absorbed in the impact. Another limitation derives from the selection of the surface on which the test is carried out, which has to be bare (i.e. without plaster and/or any other material) and is a structural concrete component.

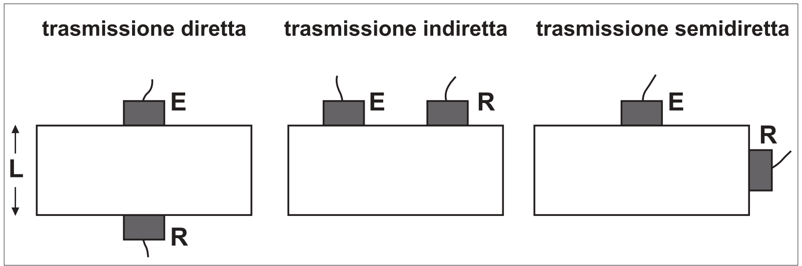


Plate 3.4: Methods for ultrasound reading; a) opposite position (direct), b) on the same surface (indirect), c) at an angle (semi-direct)

3.4.2 The ultrasound test

This test follows the requirements of the standard UNI EN 12504-4:2005. The device used for the test consists of an emitter of mechanical impulses (Plate 3.3) and of a receptor, preferably positioned on the opposite sides of the investigated component.
The test entails measuring the time in which the ultrasound waves have passed through a component positioned between the two transducers at a given distance to obtain the speed of transmission V. Therefore, it is possible to calculate the speed V of an ultrasound wave by noting the distance of impulses and measuring the time between the instances of emission and reception of the signal.
However, as concrete is not a homogenous medium, isotropic and elastic, the relationships that link the speed of transmission with the medium's mechanical characteristics have to consider the real physical and chemical properties of concrete. Readings can be made in different ways, each one related to a different position between the two transducers (Plate 3.4.).
Particular attention should be given to the grip between the instruments and the surface of the investigated component. Different mediums are used to achieve better grip between the instruments and the surface.

[7] Masi A., *La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive*. Il Giornale delle Prove non Distruttive Monitoraggio Diagnostica, n. 1, 2005, pp. 4-5.

Along with the assessment of the concrete resistance, this investigation enables obtaining the dynamic elasticity module and the Poisson module[8].

The test results can be affected[9] by the type of cement, the size of aggregates (the variety of granulometric composition of concrete could increase the speed even at equal resistance), water/cement proportions, the age of concrete (the speed is inversely proportional to the age level), humidity level[10] in concrete (higher speed[11] is registered when humidity increases), the level of stress[12] within the investigated component and the position of reinforcements.

An example of the first qualitative interpretation of data collected in situ (Table 3.5) is a comparative table (taken from a study by the Italian National Rail Research Institute[13]) which links the speed of spread of the ultrasound waves with the resistance of material (Table 3.6).

A similar study by Adam M. Neville[14] had enabled the elaboration of a table in which the quality of concrete was determined on the basis of the speed of the impulse spread (Table 3.7).

In existing buildings, the knowledge on the concrete typology is fundamental to guarantee the reliability of investigation results. For instance, from 1970´s and 1980´s the cement conglomerates prepared by using a granulometric curve became common, while in 1950´s and 1960´s the concrete was made by using a dosage of highly diversified granulometric content.[15]

Zocca - Di Lena sperimentale F.S.	Velocità Media [m/s]	Condizioni
	>4570	Eccellenti
	4570 - 3660	Buone
	3660 - 3050	Accettabili
	3050-2130	Cattive
	<2130	Pessime

Table 3.5: Comparative table: speed of spread – condition of concrete

Zocca - Di Lena sperimentale F.S.	Velocità Media [m/s]	Resistenza R_{cub} [MPa]
	>4200	>30,00
	4200 - 3600	30,00 - 25,00
	3600 - 3000	25,00 - 20,00
	3000-2400	20,00 - 15,00
	<2400	<15,00

Table 3.6: Comparative table: speed of spread – resistance of concrete

Adam M. Neville	Velocità Media [m/s]	Qualità
	>4500	Eccellente
	4500 - 3500	Buono
	3500 - 3000	Dubbio
	3000-2000	Mediocre
	<2000	Pessimo

Table 3.7: Comparative table of the speed of spread – concrete condition

[8] The Poisson module is a physical coefficient, specific to any material, that measures the level in which the material sample, submitted to the longitudinal mono-directional pressure, constricts or expands across.

[9] Masi A., *La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive*. Il Giornale delle Prove non Distruttive Monitoraggio Diagnostica, n. 1, 2005, p. 6.

[10] American Society for Testing and Materials (ASTM), 2002. Standard Test Method for Pulse Velocity Through Concrete, ASTM C 597 – 02.

[11] Christaras B. P., *Wave velocity and quality of building materials* in Proceedings of International Symposium "Industrial Minerals and Building Stones", Istanbul (Turkey) 15-18/09/2003, pp.295-300.

[12] Braga F., Dolce M., Masi A., Nigro D., *Valutazione delle caratteristiche meccaniche dei calcestruzzi di bassa resistenza mediante prove non distruttive,* L'Industria Italiana del Cemento n. 3, 1992.

[13] Zocca A. e Di Lena M., *I controlli non distruttivi e la valutazione della resistenza del cls in opera* - Istituto sperimentale Ferrovie dello Stato – Italia, 1986.

[14] Neville A. M., *Properties of Concrete: Fourth and Final Edition,* ed. John Wiley & Sons, July 1996, ISBN-13: 9780470235270, pp.145-237.

[15] Seminar on the assessments for the preservation of built heritage held by Eng. A. Basile at the Association of Engineers of Caserta Region entitled "The NTC (Technical Norm for the Constructions) and the control of materials: technique, profession and delivery regarding new and existing buildings"

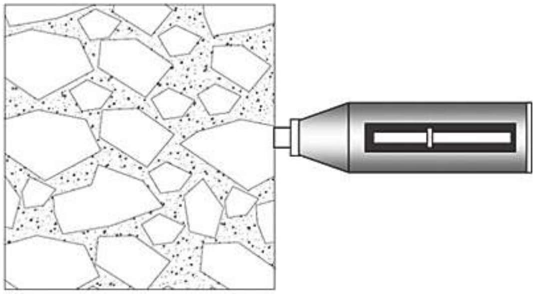


Plate 3.8: Sclerometer beats against a large piece of aggregate

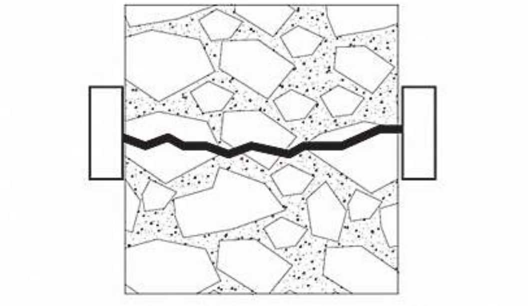


Plate 3.9: Ultrasound equipment: the impulse transmission

3.4.3 "SonReb" method

The SonReb Method *(Sonic+Rebound)* uses the combined results provided by the above described tests that incorporate a useful instrument for assessing the resistance of concrete, enabling the elimination of errors, at least partly, that appear when the two investigation methods are separately applied. This method, in fact, allows reducing the errors made when the sclerometric and ultrasound tests are undertaken separately.[16] It has been noticed, for example, that the humidity content leads to an underestimation[17] of the sclerometric index, and in an inversely proportional way leads to an overestimation of the ultrasound speed; similarly, the sclerometric index rises in a directly proportional way to the increase of the age of concrete[18] while the ultrasound speed decreases in an inversely proportional way to it.[19] In fact, the risk that can come up in the separate use of sclerometric and/or ultrasound tests is related, for example, to the chance nature of the position of aggregates in relation to the external surface of an investigated component; the sclerometer can easily beat against a large piece of aggregate, probably obtaining a higher value of the bounce index S in relation to the one returned when the blow is executed on a homogenous concrete surface[20] (Plate 3.8).

Again as an example, the ultrasound test[21] (Plate 3.9) can equally be affected by the chance nature of the disposition of aggregates in a cement mix when the gaps between the aggregates are arranged in the way that induces the rise of the void index; in this case, the speed of wave spread V decreases in relation to the value that would be obtained when the wave spreads through an area of "homogenous" concrete.

The wide-spread use of the "SonReb" (Plate 3.10) combined method owes to the fact that the execution of tests takes little time, with

[16] Braga F., Dolce M., Masi A., Nigro D., *Valutazione delle caratteristiche meccaniche dei calcestruzzi di bassa resistenza mediante prove non distruttive,* L'Industria Italiana del Cemento n. 3, 1992, pp. 200-212.

[17] In fact, the sclerometric index decreases at the increase of humidity and tends to rise with the aging of concrete due to carbonation.

[18] Masi A., *La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive.* Il Giornale delle Prove non Distruttive Monitoraggio Diagonstica, n. 1, 2005, p. 6.

[19] Bocca P., Cianfrone S., *Le prove non distruttive sulle costruzioni: una metodologia combinata.* L'Industria Italiana del Cemento n. 6, 1986, pp. 425-443.

[20] Seminar on the assessments for the preservation of built heritage held by Eng. A. Basile at the Association of Engineers of Caserta Region entitled *"The NTC (Technical Norm for the Constructions) and the control of materials: technique, profession and delivery regarding new and existing buildings"*

[21] Ibidem.

further economic advantages, and that they are minimally invasive on the structure and, therefore, do not compromise the resistance of structural components.
The application of the "SonReb" method asks for the appraisal[22] of local values of the ultrasound speed V and of the bounce index S from which it is possible to obtain the resistance of concrete Rc through expressions such as:

$$R_{c,SonReb} = a \cdot S^b \cdot V^c \quad [1]$$

In the scientific literature this formula has assumed different forms, each one expressing the experiments undertaken directly on site or in a laboratory on standardised samples.

For example:

J. Gasparik[23] (1992) $R_{c,2} = 8,06 \cdot 10^{-8} \cdot S^{1,246} \cdot V^{1,85}$ [2]

RILEM ('93)[24], NDT 4 $R_{c,1} = 9,27 \cdot 10^{-11} \cdot S^{1,4} \cdot V^{2,6}$ [3]

Di Leo, Pascale[25] ('94) $R_{c,3} = 1,2 \cdot 10^{-9} \cdot S^{1,058} \cdot V^{2,446}$ [4]

in which:
- Rc is the resistance of a cube under compression [N/mm2];
- S is the sclerometric index
- V is the ultrasound speed [m/s].

The formula [3] depicts the correlation curve applied in the investigated case studies. In [3]

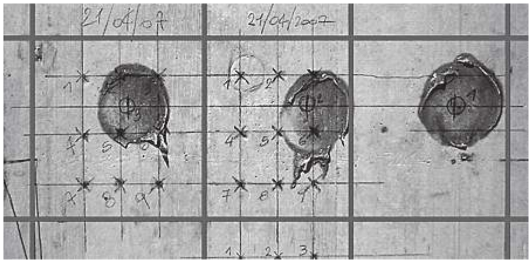


Plate 3.10: Example of measuring the bounce index and the speed of spread of ultrasound ("SonReb" method)

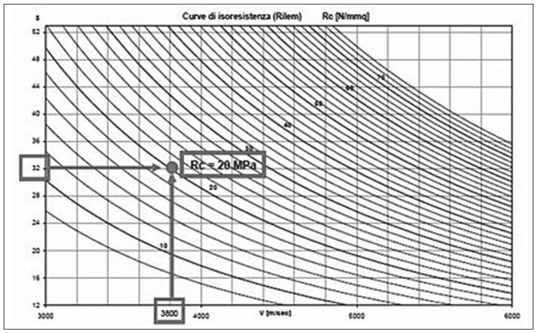
Rc is expressed in MPa and the ultrasound speed in m/s; this relationship is related to a standard concrete whose properties are described in RILEM 43-CND. When a different type of concrete is employed the following relationship is applicable[26]:

$$R_{SonReb} = R'_{SonReb} \cdot (C_c \cdot C_d \cdot C_a \cdot C_f \cdot C_p \cdot C_m) \quad [5]$$

where R'sonreb is the value obtained from (1), while Cc (cement type), Cd (cement content), Ca (aggregate types), Cf (proportions of fines), Cp (maximum aggregate size) and Cm (errors) are coefficients of influence that permit the extension of the [2] to the cases of a non-standard concrete (as defined above).
Hence, if the concrete has the same characteristics as the one whose experimental curves are available, the graph directly provides the estimated resistance of concrete. Otherwise, as usually happens, when the concrete has a different composition from the one presented by the curve, the corrective coefficients, that take into account the type of cement and the

[22] Di Leo A., Pascale G., *Prove non distruttive sulle costruzioni in cemento armato,* Convegno Sistema Qualità e Prove non Distruttive per l'affidabilità e la sicurezza delle strutture civili, Bologna - SAIE, 1994.
[23] Gasparik J., *Prove non distruttive nell'edilizia,* Università di Brescia 1992, pp.80-92.
[24] RILEM Draft Recommendation, 43-CND, *Combined non-destructive testing of concrete. Draft recommendation for in situ concrete strength determination by combined non-destructive methods.* Materials and Structures n. 26, 1993, pp.41-52.
[25] Di Leo A., Pascale G., *Prove non distruttive sulle costruzioni in cemento armato,* Convegno Sistema Qualità e Prove non Distruttive per l'affidabilità e la sicurezza delle strutture civili, Bologna – SAIE, 1994, pp. 25-36.
[26] Giochetti R., Lacquaniti L., *Controlli non distruttivi su impalcati da ponte in calcestruzzo armato,* Nota Tecnica 04, Università degli Studi di Ancona, Facoltà di Ingegneria, Istituto di Scienza e Tecnica delle Costruzioni, 1980.

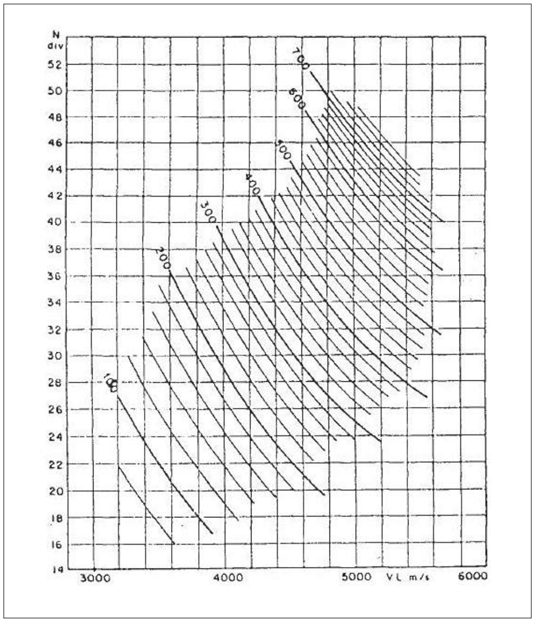
Table 3.11: Isoresistance curves – RILEM NDT 4 recommendations



related dosage, the nature and dimensions of aggregates, and the potential additives, need to be applied to obtain an approximately true estimate of the concrete resistance.[27]

It is evident that the above equations could not have universal validity except for the fact that the values of S and V depend on the characteristics of concrete, even when the specific indications on the limitations of applicability are missing.

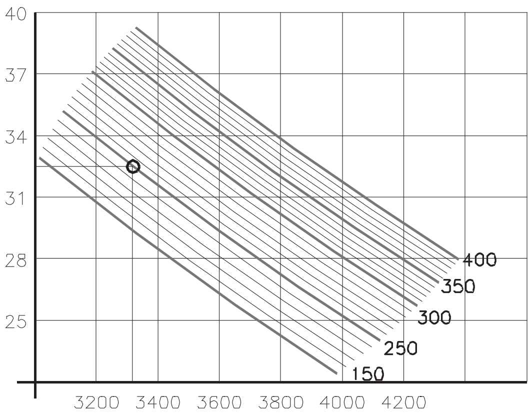
Table 3.12: Isoresistance curves obtained by P. Bocca and F. Cianfrone



However, a qualitative appraisal of the resistance of concrete can be made even by using the graphs (Table 3.11, 3.12, 3.13)[28] which show a series of isoresistance curves in the plane V-S (obtained from the above analytic expressions) and which refer to the tests undertaken on standardised samples in a laboratory.

Although it appears absolutely necessary to analyse a wider range of cases, the above methodological investigation approach, based on the comparative analysis of the two described test campaigns, suggests several important considerations regarding the modality of investigation and the interpretation of results, demonstrating the need for establishing general investigation criteria: more than defining in a strict manner the number of tests that should

Table 3.13: Isoresistance curves obtained by Facarou



[27] Masi A., La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive. Il Giornale delle Prove non Distruttive Monitoraggio Diagonstica, n. 1, 2005, p.6-8.

[28] In analogy with what was said about the analytical expressions, even the curves have assumed different values, depending on whether the experiments were undertaken directly on site or in a laboratory on standardised samples.

be undertaken, it would be necessary to preset the level of significance to be achieved.
SonReb method, therefore, allows a quick and an economic way to obtain reliable qualitative results on the resistance of *in situ* concrete, permitting to carry out effective preliminary evaluation required for the explanation (and further design) of the restoration interventions to be undertaken on the investigated architecture.

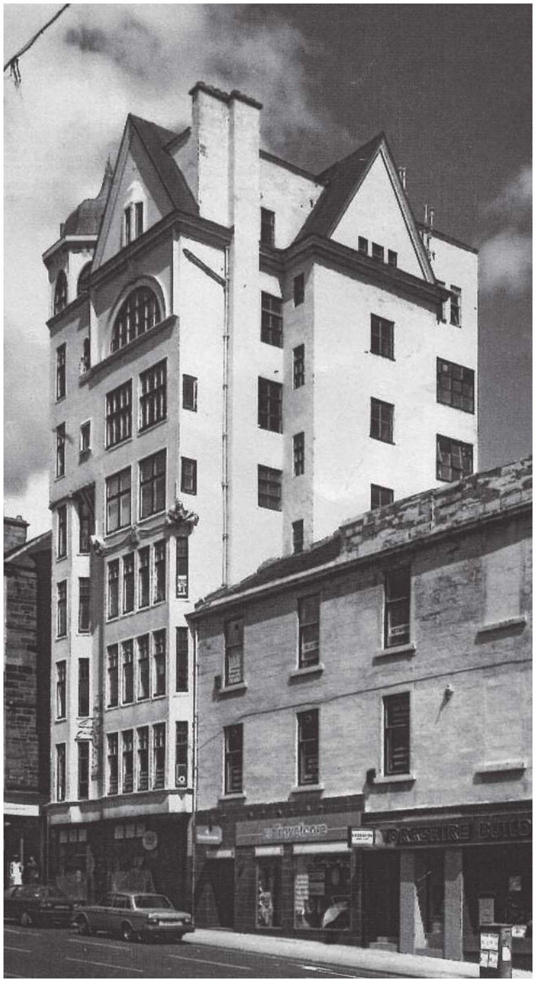


Table 4.1: Lion Chambers

4.1 **The case studies**

The analysis undertaken so far and the discussion on tentative diagnoses need to be applied on site and require a validation of obtained data. Therefore, two case studies were selected, two architectural examples that represent two significant moments in the architectural culture of the places in which they emerged. Their importance is fundamentally linked to what they represent in the architectural debate on techniques and technologies regarding the construction sector at the start of the 20th century. The buildings are the Lion Chambers in Glasgow (Plate 4.1), designed by the Scottish architects J. Salmon Jr and J. Gillespie and built between 1904 and 1907, and the Duni Theatre in Matera (Plate 4.2)[1], designed by the Materan architect E. Stella and built between 1946 and 1949.

These two buildings, although of different use (the first one is an office building for local lawyers, the second one is a movie theatre), time of construction, form and size, finishes and materials, technological and structural systems, are linked by being both among the first realisations in reinforced concrete in the places in which they were built. In fact, although built almost forty years apart, they represent a synthesis of what the debate in architectural field was in those years and in specific social, cultural and economic context in which the two buildings were concei-

[1] See Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare"*, Edizioni Librìa, Melfi, 1999, p. 9 – foto VASARI (1949) Roma.

ved, designed and, finally, built. Two significant examples of this technical and technological evolution in the architecture of the 20th century, with different rudimentary consequences in 1920's in Scotland and 1950's in Italy.

4.2 **The Lion Chambers - Glasgow (UK)**

4.2.1 Building location – Hope Street and its environs and the adjacent building

The Lion Chambers was built at 172 Hope Street. The street leads uphill from Argyle Street at its south end to Cowcaddens Road at the north within the rectangular city centre grid. Transitions from Victorian architectural historicism to Edwardian 'Free Style', and then Art Nouveau and Modernism are vividly present in this street. If the architects' names were on the buildings that they designed, the walk through the Hope Street would show a large part of 'who was who' list of the architects of that era.

One of the reasons for the concentration of big architectural names and their works in this street in the last decades of the 19th century was because this city area attracted investment for buildings around the Central Station which was built at the south end of Hope Street in 1879. The station was fronted with a huge Victorian building, planned initially as offices but opened as a hotel in 1884. It was designed in Northern European Renaissance style by the architect Sir Robert Rowand Anderson (1834-1921) and extended by James Miller (1860-1947) in 1900-8.[2] The four-storey building of polished ashlar carries a double attic composed of a series of decorated gables. The Central Station and the hotel created a monumental entrance for people and goods to Glasgow. Building plots in the streets in the vicinity of this busy area attracted investment in new buildings and challenged other architects to come up with impressive designs to demonstrate the prosperity of Glasgow at that time to visitors and businessmen.

The Lion Chambers rises on a small plot (46 ft 1 in by 33 ft 1 in)[3] at the corner of Hope Street and Bath Lane, next to the building which was also owned by William George Black, as noted in the original site sketch drawing.[4] A set

Table 4.2: Main entrance of Duni Theatre

[2] Williamson et al., p. 210.

[3] 14.05 m by 10.08 m. Measures provided in Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly)*, 30 January 1907.

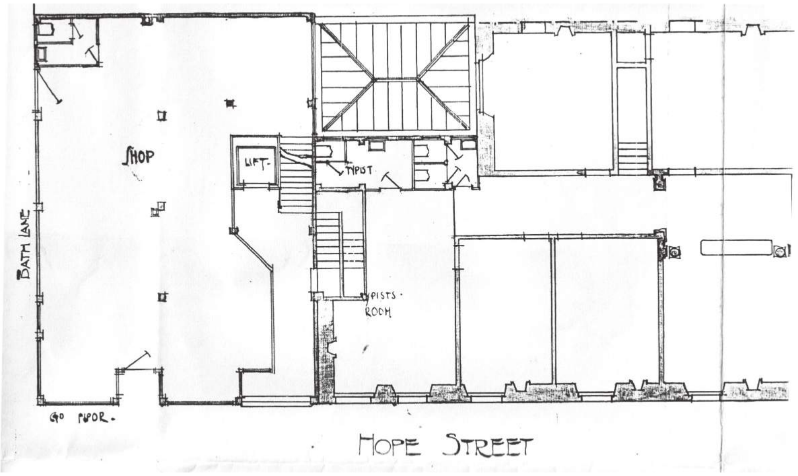


Table 4.3: Ground floor plan

of thirteen plans of the Lion Chambers were submitted to the city authorities on 1st June 1905, as indicated on one of them, but the dates on individual drawings show that they were made from April 1904 until April 1905.[5] The plans of the existing building, south of the Lion Chambers, were also included (basement, ground floor, first floor and second floor). The facade view shows that there was a small, one-storey building with a pitched roof on the Lion Chambers plot.

The existing building to the south had a circular staircase in the northeast corner. The plans of the basement, ground floor and first floor of the Lion Chambers show that a connection with the existing building was planned by removing the circular staircase. Instead, a room was created at the basement of the existing building and the wall to the Lion Chambers basement removed. This remodelled basement space in the existing building was then covered with a pitched glass roof to provide natural light to both basements.

Next to the adapted basement room, simple new stairs and reinforced concrete columns were built to carry new corridors and a new set of toilets on the ground and first floor within the existing building. The new corridors at these floors are connected with the Lion Chambers. It was difficult to build a tall structure (90 ft from the pavement level and 100 ft from the basement level)[6] in the limited space in Glasgow's busy city centre. However, the contractors were as inventive as their construction system in solving this problem, as explained in more detail below.

4.2.2 Original building use, layout and services

The area available for a useful occupation of the nine floors of shops and offices is 11,070 sq feet.[7] The basement and ground floor were planned for a firm of printers and stationers, the upper floors for lawyers' offices, and the top floor for 'artist painters'.[8] William George Black's links with artists and his philanthropic inclinations had probably influenced the decision to provide space for artists in his new building. As Anne Robertson Black, William's wife,

[4] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 19th 1905. *Proposed Building Hope Street for Wm Geo Black Esq. Block Plan.* A section of the copy of the original drawing. Four Acres CharitableTrust.

[5] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, March 1905. *Proposed Building Hope Street for Wm Geo Black Esq.* The Mitchell Library Archive, Glasgow.

[6] 27.04 m and 30.48 m. Measures provided in Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907

[7] 1,028.44 m2

[8] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907

was a daughter of the publisher Robert Blackie of Blackie and Sons Ltd founded in 1809[9], this publishing link might have led to planning the basement and ground floor spaces for a related business. The plan of the elevation to Hope Street shows the shop name 'Douglas'.[10] G. A. H. Douglas & Co are still listed at the address 172 Hope Street in Glasgow Online directory[11] and the business name is still above the shop window, but the shop was vacated in late 2009 by its original occupants since 1907.[12]

The open-plan basement and ground floor are connected to the adjacent building (Plate 4.3).[13] The plan of the first floor, published in 1907,[14] shows six offices in two groups, accessed from a divided entrance corridor that is connected to the stair landing (Plate 4.4). In each group, one of the offices was named as public and the other two as private rooms. There are two safe rooms, each accessed from one of the corridors. Separate rooms in an office building were an established layout concept, especially suited for lawyers' offices where privacy of communication with clients is required. As the structure made of reinforced concrete columns and slabs provided an opportunity for open-plan spaces, they were created in the basement for printing works and at the ground floor for a shop.[15]

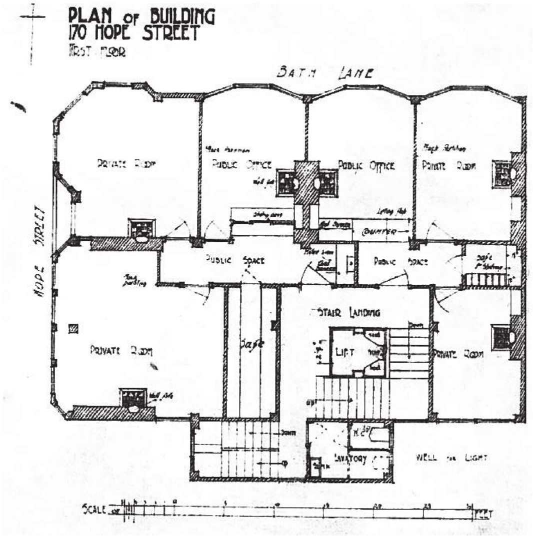


Table 4.4: First floor plan

Three studios were planned on the 7th floor, each with two stoves and running water, according to the plans dated April 1905.[16] Access to the top floor was made easier with the lift in the centre of the square staircase.

Some of the occupied rooms were heated with Carron stoves, installed by Carron Co.[17] Others had fireplaces with cast iron mantelpieces.[18] The position of each fireplace or stove was indicated in the plan with floor tiles and a surrounding border next to chimneys. Carron stoves are still

[9] Records of Blackie & Son Ltd, publishers, Bishopriggs, Glasgow, Scotland. Archives hub at http://archiveshub.ac.uk, accessed on 24/03/2011.
[10] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, *Proposed Building Hope Street for Wm Geo Black Esq. Elevations,* April 1905. The Mitchell Library Archive, Glasgow.
[11] http://www.glasgowonline.co.uk, accessed on 29/03/2011.
[12] Blaikie, G. (2011) Victorian Glasgow. Commercial Buildings. At http://www.scotcities.com, accessed on 25/03/2011.
[13] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 19th 1905. *Proposed Building Hope Street for Wm Geo Black Esq. Ground floor plan.* The Mitchell Library Archive, Glasgow.
[14] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907
[15] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 19th 1905. *Proposed Building Hope Street for Wm Geo Black Esq. Ground floor plan.* The Mitchell Library Archive, Glasgow.
[16] Ibid, 7th floor.
[17] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907
[18] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 19th 1905. *Proposed Building Hope Street for Wm Geo Black Esq. Detail of SW office on 2nd floor.* The Mitchell Library Archive, Glasgow.

being made[19]. The electric elevator installed in the Lion Chambers was among the earliest applications after its invention in 1902 by the Otis Elevator Co as the first system was installed in New York in 1904.[20] Brothers Alexander and Peter Steven, who installed the elevator, set up in business as hydraulic engineers in 1850 and specialised in lifts. The electric lift they introduced in 1897 was one of the first made in Scotland.[21]

4.2.3 Exterior design

Regarding the architectural design, the anonymous author of an article about the Lion Chambers, published in 1907, wrote the following:

"Messrs. Salmon and Son and Gillespie explain that the material and the purpose of building suggested the treatment. No effort was made to imitate a stone or brick building, but as ample daylight in office is of high importance in a city, large and projected windows were made the predominant features. The corner oriel window has been carried above the roof and finished with a dome, which has been made an internal feature of one of the studios on the top floor. Two modelled corbels, representing legal dignitaries, help to support the main oriel window. The name of the building, 'Lion Chambers', is given on the modelled panel, surmounted by the coat of arms and motto of the proprietor, which is intended to be painted in heraldic colours."[22]

Although the importance of the building material and purpose, and the need for natural light in offices were emphasised, the creative thinking that led to the final design was not explicit in the above comment, but was made clearer in Salmon Jr's lecture in 1908. The design can also be better understood within the context of the ideas shared by the architects in Glasgow and the construction capabilities of that time. As the introduction of steel frames enabled the use of large glass surfaces on Glasgow's building facades, Salmon Jr skilfully demonstrated on the 'Hat-rack' a novel approach to the design of facades. Reinforced concrete represented a new challenge for Salmon, Son and Gillespie. The design of the structure was in the safe hands of Hennebique's engineers. However, regarding the building envelope, they provided only advice on the required thickness of the facade walls and external surface rendering. As the external walls of the Lion Chambers do not have thermal insulation, it is obvious that there was no awareness that reinforced concrete is an excellent thermal sink that absorbs summer heat and then releases it into rooms, and absorbs winter cold causing condensation of vapour on internal surfaces. Thus, the external walls, roof and foundation slab of the Lion Chambers behave as a 'cold bridge' in today's terms. Unaware of this problem, Salmon, Son and Gillespie focused on designing elevations that provided required natural light to offices and adequately expressed the building material.

[19] http://www.fireplaces-radiators-stoves.co.uk/carron-downloads.asp, accessed on 19/03/2011.
[20] IEEE Global History Network, http://www.ieeeghn.org/wiki/index.php/The_Electric_Elevator, accessed on 19 March 2011.
[21] Mitchell Library, GC 338.76218770941443 STE
[22] Anonymous. A reinforced concrete office building, The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly), 30 January 1907.

The west elevation to Hope Street (Plate 4.5) is en example of Glasgow Free Style in the way it transforms and combines elements of historical architectural forms such as the oriel corner windows topped with a domed tower and the triangular gable above the cantilevered windows. Asymmetrical facade composition and different shapes and sizes of windows were also used by some architects of the Glasgow Free Style. Simple, rounded window frames and the smooth wall finish, in complete contrast to the 'Hat-rack' building, show a radical departure from Art Nouveau in direction of Modernist architecture. This departure carried along memories of Scottish castellated architecture in the building's slender form and almost white rendered elevations. However, the intention to experiment is visible in details such as the parabolic windows on the corner tower, a 'nod' to Antoni Gaudi's use of parabolic arches. Two busts of lawyers above the third floor were the work of Johan Keller[23], a Dutch sculptor who became a Professor at the Glasgow School of Art in 1898. Salmon Jr and Keller became good friends and went together on an extended tour of Europe in 1904.[24]

Plate 4.5: North and west elevations

The elevation to Bath Lane is an even bolder move towards a direct expression of building structure, materials and functions without any additional decorative elements. Glass on the soaring bays allows access of natural light to offices and reflects light that hits the panes. The top end has a tighter rhythm of windows. A potential influence of the canted bays with steel casement on the rear elevations of the Lion Chambers and Mercantile Chambers on the design of the tall library oriels on the west facade of Glasgow School of Art has been suggested as Mackintosh revised the design of the still-unbuilt western third of the building in March 1907.[25]

The windows on the plain surface of the south elevation of the Lion Chambers are placed according to the internal need for light (Plate 4.6). The composition of the top part of the whole building is completed with a triangular gable on the south facade above the cornice linked to the west facade above the sixth flo-

[23] Ibidem.
[24] O'Donnell, R., 2008, p.42.
[25] Walker, D., 1996, p.142.

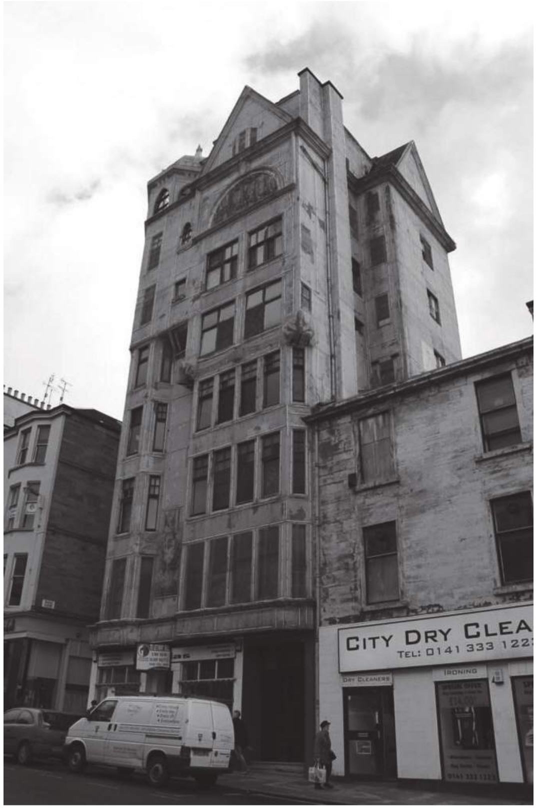


Plate 4.6: West and south elevations

or. As the east elevation faces rear facades of other buildings in the block, it is finished as a full wall with a set of plain windows of utility spaces. The freedom of independent design of each elevation has been fully exploited to satisfy and express the functional needs of internal spaces. As the external concrete surfaces were originally rendered with pale yellow cement finish, the whole building was in contrast with its immediate environment, but also within Glasgow's cityscape, apart from the equally bold south elevation of Mackintosh's School of Art. True to their designer's temperament, the Lion Chambers and the 'Hat-rack' were not shy to stand out and be noticed as the two 'buildings that stood apart from the rest'.[26]

4.2.4 Interior design

In 1890, Glasgow's City Chambers, designed by William Young[27], were completed and amazed with its opulent and high quality interior finishes. In the list of contractors on the Lion Chambers[28] there are some who had worked on the City Chambers, e.g. Galbreith & Winton, the contractors for tile and marble work, and George Adam, the contractor for wrought iron work who was a contractor for wrought-iron lamps in Glasgow's City Chambers.[29] This indicates that the quality of finishes, at least in publicly accessible spaces such as the entrance and staircase and in some offices, ought to have been very high.

A detailed plan of the office in the south-west corner on the 2nd floor, dated April 1905, shows how the interior design of this office was planned.[30] A view of the north wall contains a fireplace and two doors in brown colour, skirtings, a picture rail at the level of the door frame, and a section through timber panelling below the

[26] O'Donnell, R., 2003, p. 9.
[27] Williamson et al, 1990, p. 160.
[28] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907
[29] Williamson et al, 1990, p. 160.
[30] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 1905. *Proposed Building Hope Street for Wm Geo Black Esq. ½" Detail of SW office on 2nd floor.* Mitchell Library Archive, Glasgow.

bay window, indicating a distance between the external wall and timber panel. There is a note 'C(ast) I(ron) mantel pieces throughout' next to the fireplace.

The plan and view of the 'south oriel' windows indicates that the columns between them were panelled (Plate 4.7). The view of the east wall contains a door with framed glass on its upper part. There is a section through a timber cover for electric wires and a section through floor skirting with a note 'cork carpet'. Cork is an excellent thermal insulator and sound absorber that would reduce noise transfer through concrete slabs.

A photograph of the office in the southeast corner at the fourth floor in the Lion Chambers demonstrates that the planned interior design was followed (Plate 4.8). The dark colour of the wall below the picture rail could be attributed to panelling or paint. The cast iron fireplace is reflected on a shiny dark surface of floor tiles placed in a frame. Compared to the contemporary fireplaces, the mantel piece is quite simple, decorated only with two circular motives in the corners below the top shelf. The carpet, table, chairs and a leather armchair could have been brought from another office. Window blinds, instead of curtains, and lighting with bulbs under white glass hats, instead of chandeliers, introduce a touch of simplicity seen in American contemporary offices.

The office looks sufficiently comfortable and welcoming, without intending to impress with luxurious detail. A partition wall was inserted later between the south and north walls of the room. The windows have been replaced; the fireplace is gone as are the tiles in front of it (Plate 4.9).

Some original details of interior finishes are still in place in the entrance hall such as a door on

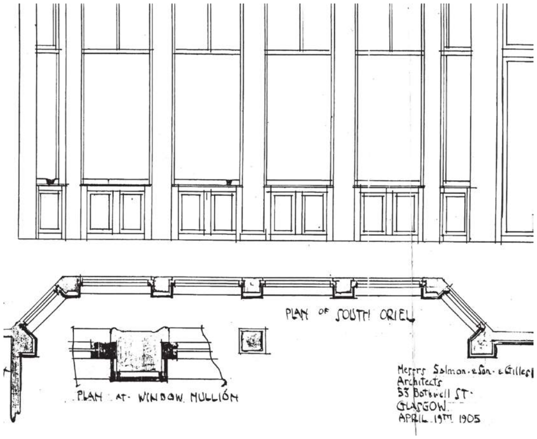


Plate 4.7: Plan and view of south oriel windows

Plate 4.8: Interior of the office in southwest corner on the fourth floor of Lion Chambers, 1907 *(© Courtesy of RCAHMS. Licensor www.rcahms.gov.uk)*

Plate 4.9: Interior of the office in southwest corner on the fourth floor of Lion Chambers, 2011

Plate 4.10: A door in the entrance hall

Plate 4.11: Original green tiles behind later panelling

the right side (Plate 4.10) and stair rail and wall tiles in shades of green at the ground level hall. The later panelling in the entrance hall covers the original tiles (Plate 4.11).

The bare simplicity of the interior design is evident in the detail of a corridor in the north part of the second floor (Plate 4.12). An exposed beam rests on the column between the office doors. Natural light floods the rooms through large windows and penetrates the corridor through glass on the doors and above them. Large windows and low parapets span spaces between columns on the north facade (Plate 4.13).

Strait lines of light shelving complement the geometrical simplicity of the rooms. The exposed structure behind the west gable on the seventh floor has a sculptural quality (Plate 4.14). Windows on the tower cupola (Plate 4.15, 4.16, 4.17) and parabolic windows in the tower walls on the seventh floor provide even north light to the interior.

Plate 4.12: A corridor in the north part of the second floor

Plate 4.13: An office in the north part of the building

The geometric simplicity of interior details is applied to the cornice above the shop window and on the entrance steps. Some original details of services are still in place, e.g. a timber mask for electric cables at the level of picture rails, switches at the ground floor and a few ceiling hooks for lighting.

Plate 4.14: Structure behind the west gable

Plate 4.15: Interior of the tower cupola

4.2.5 Structure

Regarding the condition assessment of concrete structures, it has been highlighted that although ultrasonic tests, covermeters, drill holes and other testing methods assist in the assessment, the results may be puzzling; and that the starting point in appraisal is knowledge of what is likely to be found at different dates and different types of structure.[31]

The innovative reinforced concrete structure of the Lion Chambers was presented in detail in an article published in January 1907, at the time when the work on the building was finalised. The article stated that the building had been constructed using the Hennebique system by the Yorkshire Hennebique Contracting Co. Ltd according to the structural design by L. G. Mouchel.[32]

Hennebique's system used plain round bars with fish-tailed ends and stirrups of flat strips of mild steel.[33] The stirrups provided shear resistance, although they were not mechanically anchored in the compression zone, as is the norm nowadays; column bars were linked by strips of wire.[34] From

[31] Sutherland, J., Introduction, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal,* Thomas Telford Publishing, London, 2001, p. 2.

[32] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907.

[33] Bussell, M., The era of the proprietary systems, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal,* Thomas Telford Publishing, London, 2001, p. 67.

[34] Ibidem.

Plate 4.16: Lead sheeted tower cupola

Plate 4.17: Exterior of the dome window

1897, the system included bent-up bars in beams to provide hogging resistance and supplement shear capacity, Table 4.18.[35]

A standard specification published by L. G. Mouchel & Partners in 1917[36] indicates that steel for reinforcement was to comply with BS 15 of 1912, to be Trisec bars (a patent high tensile steel).[37] Concrete proportions by volume were approximately 1.1:2:4 of Portland cement:sand:coarse aggregate.[38] The comments on testing and comparison with the design of concrete structures today assist in assessing the Hennebique system:

"The deflection criterion for passing a load test carried out on the completed structure was onerous by today's standards. Under 1 ½ times the imposed load, the structure was not to deflect more than 1/600 times the span! It should, however, be born in mind that such structures were designed using elastic modular ratio theory, with permissible stresses typically of 16,000 lb/in^2 (110 N/mm^2) in the reinforcement and of 600 lb/in2 (4.1 N/mm^2) in the compressed concrete. Consequently the section sizes and the reinforcement were more generous than a present-day design would require. A further factor – certainly for the floor slabs – is that the framing plans usually provided beams in two directions (on the precedent of iron and steel frames) The typical floor slab was accordingly supported on all four sides and, when loaded, would tend to behave more as a shallow dome in compression than as a slab in flexure, with beams acting both as supports and perimeter ties. Such behaviour would generate smaller deflections in the slabs."[39]

Table 4.18: Hennebique's proprietary system (Bussell, M.,The era of the proprietary systems, in Sutherland, R. J.M., Humm, D. and Chrimes,M. (eds.), Historic concrete: background to appraisal,Thomas Telford Publishing, London, 2001, p. 69).

Form of tension bars	Form of compression bars	Form of shear reinforcement	Method of fixing shear reinforcement	Direction of shear reinforcement
Round straight bars and round bars bent up near supports	Round straight bars	Steel strip bent to U-shape and made with spring clip	Sprung on to tension bars and bent over for anchorage in concrete	Vertical

[35] Ibidem.
[36] L. G. Mouchel & Partners, Standard Specification for Ferr-Concrete. L. G. Mouchel & Partners: London, 1917. Quoted here from Bussell, M., The era of the proprietary systems, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal,* Thomas Telford Publishing, London, 2001, p. 70.
[37] Engineering Standards Committee. Standard Specification for Structural Steel for Bridges and General Building Construction. Engineering Standards Committee: London, 1912, BS 15. Quoted here from Bussell, M., The era of the proprietary systems, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal,* Thomas Telford Publishing, London, 2001, p. 70.
[38] Bussell, M., The era of the proprietary systems, in Sutherland, R. J. M., Humm, D. and Chrimes, M. (eds.), *Historic concrete: background to appraisal,* Thomas Telford Publishing, London, 2001, p. 70.
[39] Ibidem.

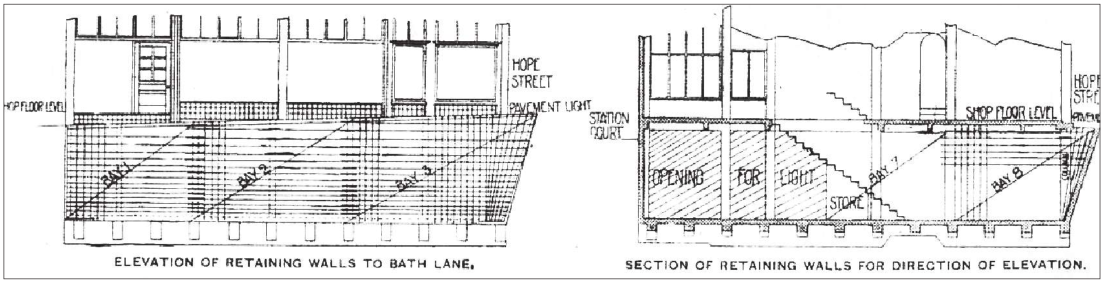


Plate 4.19: Retaining walls to Bath Lane

Hand-mixing was common, although mixing machines were also used. Mouchel's specification called for 6 cwt (305 kg) of cement to be batched with 13 ½ ft³ (0.38 m³) of sand and 27 ft³ (0.76 m³) of coarse aggregate to give a 1.1:2:4 mix, with a probable cube strength of around 15-20 N/mm².[40] Placing would be by spade or shovel and compacting by ramming, tamping or 'punning' by hand with a variety of tools including a rod with an enlarged box-end and another shaped like a hockey stick.[41] The concrete was made wetter to ensure that it flowed more readily around the reinforcements.[42]

Reinforcements in concrete walls and foundations of the Lion Chambers were shown in the plans with the article published in 1907. The 42 vertical and 15 horizontal reinforcements built within the retaining basement wall to Bath Lane were presented in a cross-section drawing. This drawing also shows the cross-section of twelve foundation beams, with an axial distance of approximately 117 cm, below the retaining basement wall (Plate 4.19).

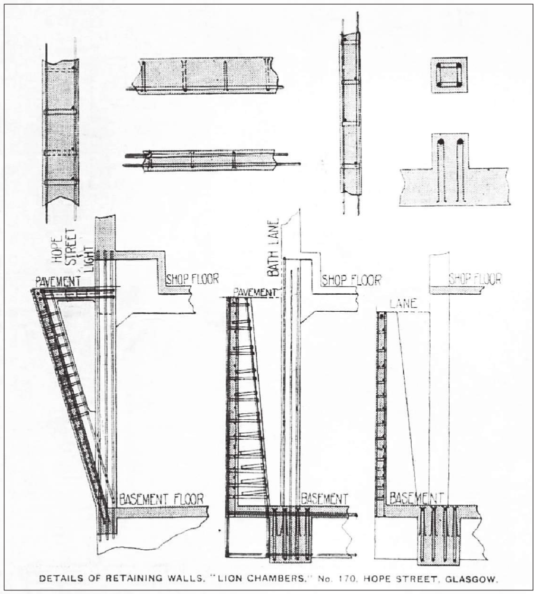


Plate 4.20: Retaining wall to Hope Street

The east-west cross-section of the basement shows primary and secondary beams in the building foundation and ground floor. As this cross-section is through the centre of the plan, the beams' size is reduced. This drawing also shows a cross-section through the inclined wall towards Hope Street where an opening at pavement level allows access of natural light to the basement through a thick semi-prism glass on a metal grid, and the view of natural light access to the basement from the glass roof in the south-east corner which is linked to the adjacent building's basement (Plate 4.20).

[40] Ibidem, p. 76.
[41] Ibidem, 77.
[42] Ibidem.

Plate 4.21: Details of roof and roof windows

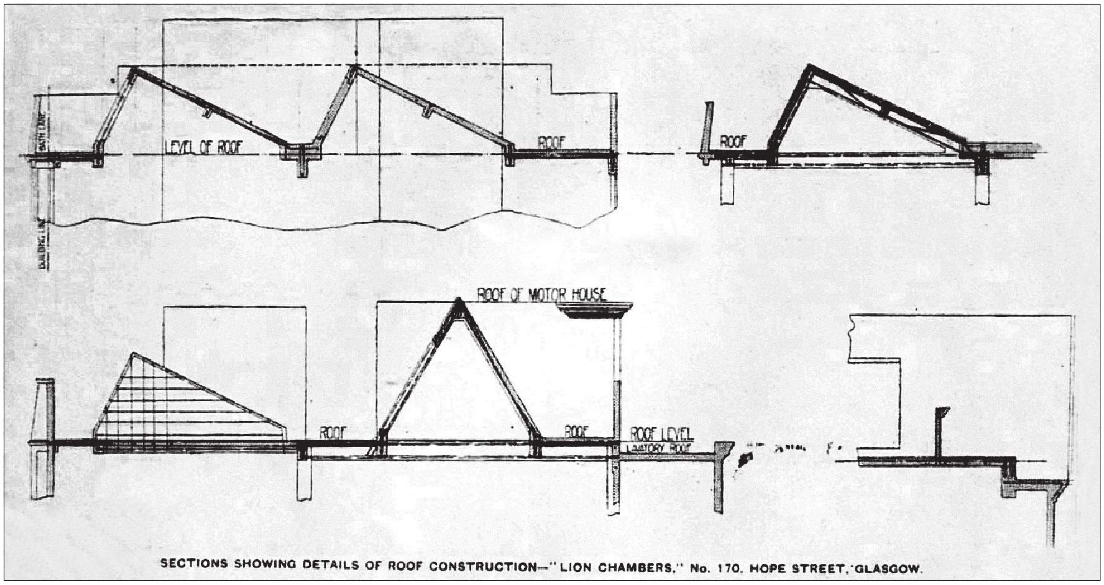
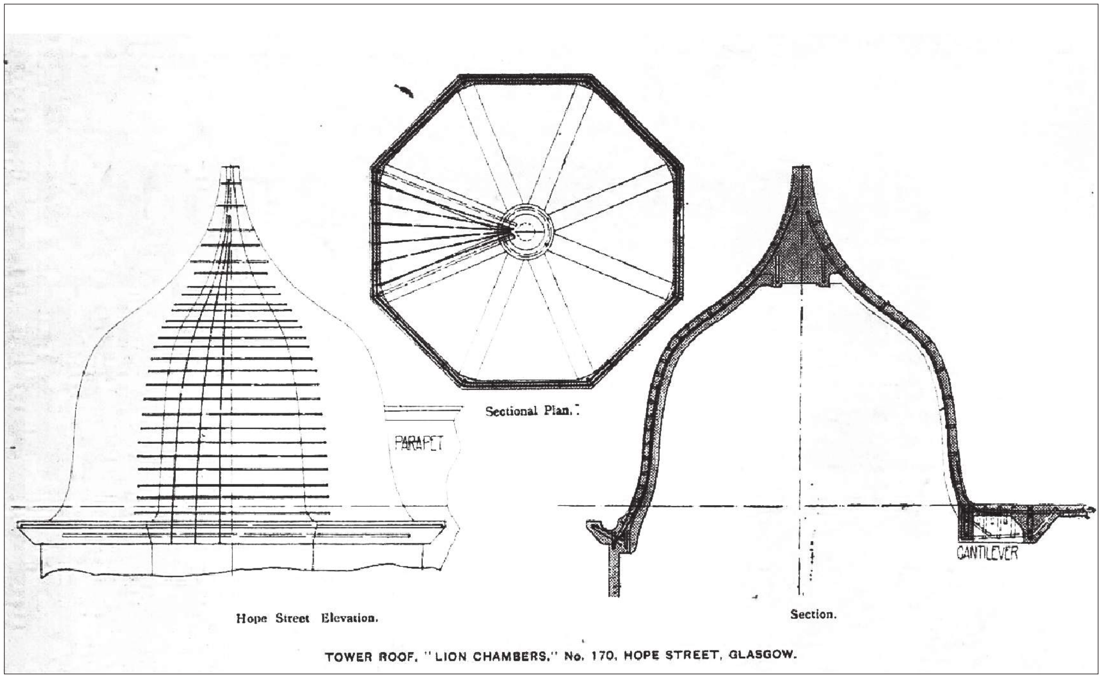


Plate 4.22: Details of the tower cupola



Three sections of retaining walls to Hope Street, Bath Lane and the back courtyard show reinforcements in the walls and a supporting inclined structure whose base is wider than its top. Other structural details also include reinforcing bars, e.g. the section through the corner oriel on Hope Street front; the cantilevered bays on Bath Lane; the roof next to Bath Lane with inclined slabs that provide access to natural light from the north into artist studios at the top floor (Plate 4.21); and the plan and section of the tower cupola (Plate 4.2). A plan of a bay window in Bath Lane shows a rectangular grid of reinforcing bars in the slab and the reinforced concrete columns with eight vertical bars and double horizontal braces around them.

The original floor plans, completed in April 1905, indicate that the columns' size is 10ins x 10ins and the thickness of the external walls 4 ins.[43] A note on the cover of the set of drawings completed in 1905 provides some additional information on structure and services:

"1. All the constructional work of this building is to be of FerroConcrete by the Hennebique Co (The system adopted at Allie & McLellan's New workshops Polmadie[44]) and will be constructed to carry a safe superload on every floor of 1 5/8 cwts[45] on each sq. ft.[46] (the safe load is calculated at 1/5th of the breaking strain). On completion and before occupying any part will be tested up to 2 cwt per sq ft and the deflection is guaranteed by the Hennebique Co not to exceed 1/600 of the span. The floor to practically recover itself on removal of the load.

2. There is a small Palmer's travelling cradle to be used as a slaters' scaffold so that the outside of walls & windows may be cleaned, pointed & painted with perfect security.

3. There are only two floors above 60' from the street, the lower one containing two small 3 room offices and the upper 3 studios. There is a fireproof stair 4' wide & a subsidiary stair 2'6" wide (also fireproof), the latter leading up to roof. This building is entirely fire proof & inflammable materials are reduced to a minimum. The Palmer's cradle could be used as a fire escape."[47]

As it was not possible to use outside scaffolding, the structure was built from within, floor by floor, enabling flying scaffolds to be cantilevered off each floor for outside work. Limited space also prevented the use of a concrete mixing plant, and the concrete was mixed by hand using the proportions 'always employed for Hennebique work'[48]. Timber moulds were used for cornices. Plaster moulds reinforced with steel were used to form medallions, keystones and busts, but heavier decoration elements were cast beforehand and afterwards fixed in place.[49]

[43] 10.16 cm

[44] Stephen Alley and John Alexander MacLellan set up a partnership in 1874 to found the Sentinel Engineering Works at 76 London Road, Bridgeton. Their head office was in Renfield Street, Glasgow. The business started manufacturing industrial valves. The growing business moved to Polmadie, south of Glasgow around 1880, where they started shipbuilding and marine machinery, double-cylinder engines, air compressors, steam wagons and boilers for steam locomotives, transmission gear, etc. Hughes, W.J. and Thomas. J. L., *'The Sentinel': A history of Alley & MacLellan and The Sentinel Waggon Works,* Volume One: 1875-1930, David & Charles, Newton Abbot, 1973., p. 15-118.

[45] 1 cwt = 45.3 kilograms

[46] 1 sq. foot = 0.09290304 sq. metres

[47] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 1905. *Proposed Building Hope Street for Wm Geo Black Esq.* Cover. Mitchell Library Archive, Glasgow.

[48] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907.

[49] Ibidem.

Cement mortar was used to render the frontages. The flat roof was constructed of reinforced concrete and covered with bituminous material except on the cupola and steep-pitched portions of the roof which were rendered with cement mortar. The anonymous writer of the article emphasised the attention given to building a very solid foundation 'consisting of a general sill spreading the loads brought by the columns equally over the whole area of the site'[50].
'Mack' partitions separate internal spaces except next to the staircase whose walls were made of reinforced concrete.[51] The partitions (plaster with embedded reeds) were built off-site[52] by Stuart's Granolithic Stone Co.[53], the contractors who had experimented with reinforced concrete.[54]

4.2.6 Contractors

The contractors[55] of this pioneering work were for Reinforced Concrete Work, Yorkshire Hennebique Contracting Co. Ltd, Leeds; for Joiner Work, Geo. Laird & Son; for Plumber Work, Steel & Wilson; for Plaster Work, J. & J. Bottomley, Marsden[56]; for Painter Work, Thomas Laurie & Co.; for "Mack" Partitions, Stuart's Granolithic Stone Co.; for Bitumastic Enamel on Roof, Wailes, Dove & Co., Newcastle-on-Tyne; for Tile and Marble Work, Galbraith & Winton[57]; for Heating Apparatus, Messrs. Combe & Son; for Electric Elevator and Enclosures, A. and P. Steven[58]; for Electric Lighting, Claud Hamilton Ltd[59]; for Lightning Conductor, Wm. Harvie & Co. Ltd; for Grates, Well Fire Co. Ltd; for Stoves, Carron Co.[60]; for Figure Sculpture Work, Johan Keller; for Modelled Ornament, Geo. Gregory; for Wrought Iron Work, Geo. Adam & Son; for Pavement Lights, Hayward Bros. & Eckstein Ltd; for Safe Doors, Donald Clerk & Son Ltd; for Ironmongery, J. L. Macindoe & Co. Consulting Electricians were J. E Sayers and Caldwell. Mr Alex McLay was the Clerk of Works. The pavement lights in Hope Street were installed by Hayward Bros. & Eckstein Ltd, a company based in London which patented "Improvements in Pavement Lighting" in 1871.[61] Their system provided natural light to a basement through a thick semi-prism glass placed between T-shaped steel bars.[62]

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[50] Ibidem.
[51] Messrs. Salmon & Son & Gillespie Architects, 53 Bothwell St, Glasgow, April 1905. *Proposed Building Hope Street for Wm Geo Black Esq. 1st floor plan.* Mitchell Library Archive, Glasgow.
[52] O'Donnell, R., 2003, p. 113.
[53] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907
[54] Cusack, P., Lion Chambers: a Glasgow experiment, *Architectural History,* 1985, vol. 28, pp. 199.
[55] Anonymous. A reinforced concrete office building, *The Builders Journal and Architectural Engineer: Concrete and Steel Supplement (Monthly),* 30 January 1907
[56] Marsden is a large village in West Yorkshire, England
[57] Galbraith and Winton made the marble staircase of the City Chambers. Hume, John R., *The Industrial Archaeology of Glasgow,* Blackie, Glasgow and London, 1974, p. 92.
[58] A. & P. Steven's Provanside Engine Works were in 181 St Lames Rd since 1865. Hume, John R., *The Industrial Archaeology of Glasgow,* Blackie, Glasgow and London, 1974, p. 209.
[59] Claud Hamilton Electrical Services Ltd still operates in Bridge of Don, Aberdeen.
[60] Carron Company had a warehouse at Port Dundas (c1830) and later in Buchanan Street. Hume, John R., *The Industrial Archaeology of Glasgow,* Blackie, Glasgow and London, 1974, p. 65.
[61] Hayward Brothers Timeline. http://glassian.org/Prism/Hayward/timeline.html, accessed on 19/03/2011.
[62] The Best of British Engineering 1750-1960. Hayward Brothers and Eckstein.
http://www.gracesguide.co.uk/wiki/Hayward_Brothers_and_Eckstein, accessed on 19/03/2011

4.2.7 Preservation actions

"I think there are many buildings in Glasgow in this situation – they are there, they are different, we all know them, but we often don't have or take the time to find out about them. Then, just as we have the time to look and consider them, assess why they seem to stand apart and make difference, they become empty, fall into disrepair and are lost. This is a loss not only for the building's owners and users, but perhaps more importantly, for ourselves – because the quality that made them stand out is gone forever. It no longer tells us its story, it no longer makes us stop and look, and it no longer makes us think.", Raymond O'Donnell, 2003.[63]

The Lion Chambers' uniqueness was recognised with the category 'A' listing in 1966.[64] However, by the late 1980's the building was in need of significant repair. In 1991, a report on the condition of the Lion Chambers and the adjacent building, with which it is connected, was provided to Historic Buildings Council of Scotland together with the application for a repairs grant.[65] The report included information that a full structural survey had been submitted in March 1991 and that during the investigation temporary propping of the basement and ground floor had been installed. The structural survey showed that water penetration had affected the concrete structure and its reinforcement due to leaks from the roof, and that the defects in external walls had been aggravated by condensation. There was general deterioration of windows. The basement was affected by damp penetration and intermittent flooding. Carbonation of the concrete structure, resulting in severe corrosion of the reinforcement, was highlighted as the most serious defect, requiring major structural repairs in order to save the building and extend its useful life. Despite this, the structural report concluded that the superstructure remained stable.[66]

Other notes on the building's condition in 1991 included comments that the lead on the cupola was slightly damaged; all other roof surfaces were covered with bituminous felt which was not in good condition; there were cracks in the render on all facades, but only hairline on the east wall which was re-rendered in 1978; patches of render were missing; there was widespread cracking on window sills on all elevations and at window heads on the rear facade. The structural damage was worst at the basement where "columns have split exposing severely rusted steel reinforcements and stirrups."[67]

The 1991 report recommended removing render off all facades to identify and repair damage; repointing joints between the concrete frame and infill panels with epoxy mortar; carrying out alkali silica reaction tests on aggregate; protecting concrete from carbonation by either cathodic protection or re-alkalisation; and undertaking structural repairs. The report noted that windows on the north facade (in metal frames) were in better condition compared to timber window frames on other facades; some timber windows were replaced, but the

[63] O'Donnell, R., 2003, p. 9.
[64] Statutory List, 168 Hope Street, Category A, Glasgow City Council, 06/07/1966.
[65] Architect's Report, Historic Buildings Council for Scotland, Lion Chambers 170/172 and 168 Hope Street/86 and 88 West Regent Street, Glasgow; File No: FHL/B/SL/176, Date of visit: 22 August 1991.
[66] Ibidem, p. 1.
[67] Ibidem, p. 3.

report notes that those on the second floor seemed original.[68]

Internal inspection reported widespread efflorescence on the internal surfaces of external walls with the comment that 'as the walls are uninsulated it is probable that condensation on the surface and within the walls is contributing to carbonation of the concrete and corrosion of reinforcement.'[69] The recommendation was to remove internal plaster, dry out walls and re-plaster after external walls had been made waterproof. There was no mention of thermal insulation of external walls to prevent future condensation.

In March 1995, as no works were undertaken following the above report, Glasgow City Council issued a Notice Requiring Operations on a Dangerous Building related to the Lion Chambers and the adjacent building, asking the owners to reinstate the structural integrity of the building.[70] In April 1995 the seven co-owners of the block were refused planning permission for demolition of the category 'A' listed building. The upper floors of the building were evacuated in 1995, with only the ground floor and basement remaining in use, and scaffolding to the west facade was erected. The costs were covered by Glasgow City Council and Historic Scotland who then commissioned the Glasgow Building Preservation Trust to carry out a feasibility study on the building and to consider acquiring the property for restoration, given the inability of the numerous owners to progress a repairs scheme.[71] Scaffolding was erected around the whole building and a protective mesh placed on the facades in autumn 1996[72]. In autumn 1998, additional propping of the basement was installed, loose render was removed and broken windows sealed.[73]

In 1998, the structural survey noted further deterioration of building structure and fabric that extended to upper floors in which humidity increased without heating after they were left unoccupied. This survey concluded that due to the nature of the internal structure and the extent of carbonation, the previously considered methods of realkalisation of concrete were not applicable.[74] The proposed options for interventions in the basement included replacing the external envelope and basement structure, and propping/retaining the interior; placing new watertight membranes to the concrete raft slab and retaining walls; stripping the plaster and repair of concrete surfaces; installing new skirting panels; making new corbels to column heads; and applying an overcoating treatment to all walls, columns and floor (400 microns of elastic coating). It was recommended to use Renderoc HB and Renderoc LA for the repair of concrete surfaces. A complete replacement of the external envelope was proposed by using 150 mm light weight concrete. Replacement of the first floor slab and all the columns from ground to roof level, and of the stairway on the south elevation was also proposed. Repair of roof surfaces and new weatherproofing was recommended, but no advice was given on thermal insulation. Window replacement, re-

68 Ibidem.
69 Ibidem, p. 5.
70 Notice Requiring Operations on a Dangerous Building, Building (Scotland) Act 1959, Section 13; Address 168/172 Hope Street/88 West Regent Street, Glasgow, 8 March 1995.
71 Information from a copy of a related document provided by Four Acres Charitable Trust.
72 Ibidem.
73 Ibidem.
74 Ibidem.

pairs to internal finishes, services installation, upgrading electrical installation and new lift installation were recommended. It was suggested to re-render the rebuilt elevation, to use a protective membrane such as Dekguard "S" by Fosroc Expandite or similar, and to install an internal insulation/lining/vapour barrier to all elevations.[75] A feasibility study, completed in 1998, proposed possible new uses of the Lion Chambers such as for offices, residential use or a design centre.[76]

In May 1999, a press release was issued by Glasgow Preservation Trust pleading for financial support to save the Lion Chambers.[77] However, Historic Scotland objected to the proposed reconstruction of external walls and suggested further research into conservation and repair techniques.[78] In May 2000, a condition update report noted further deterioration of concrete elements at upper levels and continuing water penetration in the basement. There was also damage to the scaffolding which was hit by a vehicle.[79] As the scaffolding around the building was unsightly and presented risks of vandalism and fire, it was decided to remove it and protect the facades with a galvanised steel mesh in 2000.[80]

In February 2001, a feasibility study for the repair and conservation of the Lion Chambers, commissioned by Historic Scotland, concluded that additional propping of the structure was required in three other areas as the corrosion of the reinforcement had been internally exacerbated by the lack of use of the building, allowing high humidity levels to develop.[81] As it was anticipated that the full repair would not be implemented for three years, temporary maintenance was required together with the installation of netting. Some localised demolition and reconstruction of parts of the structure were envisaged during the full repair. The proposed repair solutions focused on the control of moisture within the concrete and included demolishing and recasting extensively deteriorated structural members at roof level, within the basement and the escape stair; external and internal patch-repair of damaged concrete using a concrete repair mortar matching the original constituents and including non-shrink additives; strengthening critical beams using carbon fibre bonding to improve floor loadings; repair of external render using a mix of similar proportions to the original and an application of a proprietary elastomeric coating; installing a sacrificial anode system to high risk basement columns and beams; excavating pavements to expose outer faces of basement walls and applying waterproofing externally; and installing temporary air conditioning to dry out the structure. It was recommended to trial corrosion inhibitors and/or electro-osmosis on the structure.[82]

The report also examined potential future uses in relation to Building Standards and concluded that extensive strengthening would be required in order for it to be acceptable for the office loading in line with current practice, but noted that the level of strengthening required to meet

[75] Ibidem.
[76] Ibidem.
[77] Glasgow Building Preservation Trust, *Press release: Lion Chambers,* 13th May 1999. A copy provided by Four Acres Charitable Trust.
[78] Information from a copy of a related document provided by Four Acres Charitable Trust.
[79] Ibidem.
[80] Ibidem.
[81] Information from a copy of the report provided by Four Acres Charitable Trust.
[82] Ibidem.

Plate 4.23: External protective net

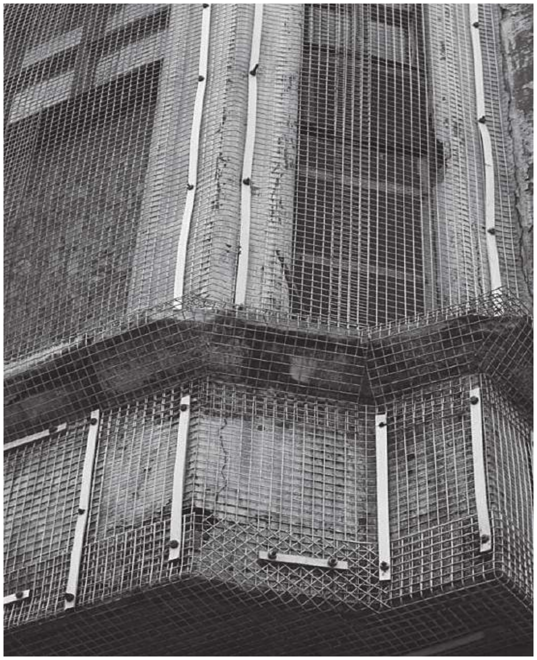

Plate 4.24: Impact of condensation on a ceiling

an imposed load 2.5KN/m^2 would be extensive and disruptive. Reduction of the imposed loading requirement to 1.5 KN/m^2, equivalent to domestic use, would significantly reduce the extent of likely strengthening and make carbon fibre bonding a feasible solution. However, it was suggested that due to the building age, a full scale load tests might be required to estimate the floor loadings for a change of use.[83]

The report also discussed thermal insulation that would be needed to satisfy requirements for fuel conservation indicating that it was theoretically possible to insulate the walls leaving a vented void (to eliminate moisture from external walls) around the internal face of the external walls. This solution would entail reducing the size of rooms and increasing the dead load. Another suggested option was to use relatively thin and lightweight proprietary products, with a comment that it was unlikely that building regulations would be met in this way. The conclusions were that a higher level of heating would be necessary than normally expected to provide a modern living environment.[84]

During this research in April 2011, the vacant building was inspected and tests on the reinforced concrete columns were undertaken. However, destructive investigation holes have not been reinstated to prevent deterioration around them. An external protective net prevents damaged render pieces from falling, but does not prevent further deterioration of the facades from weather (Plate 4.23). Condensation impact on wall and ceiling surfaces is clearly visible (Plate 4.24).

The basement is in the poorest condition. Water penetration has damaged the bases of columns (Plate 4.25).

[83] Ibidem.
[84] Ibidem.

4.2.8 Assessing the condition of reinforced concrete and selecting appropriate repair options

The following section provides a brief overview of the causes of deterioration of reinforced concrete and repair options. The causes of deterioration of reinforced concrete can be assigned to inadequate design, construction, materials and maintenance.[85] Design aspects include the consideration of the likely exposure conditions, the correct mix, more than 15mm concrete cover to the reinforcing steel, and the provision of sufficient movement joints of appropriate dimensions and location. Construction faults occur if the concrete is poorly compacted, inadequately cured, does not provide a sufficient cover to the reinforced concrete, or has a high porosity due to the addition of too much water. Materials such as calcium chloride, alkalis that instigate alkali-silica reaction and iron pyrites among the aggregates could cause deterioration of reinforced concrete structure. Lack of or inadequate maintenance (e.g. by using epoxy resin mortars) can reduce durability of reinforced concrete.[86]

Corrosion of steel reinforcement in concrete can occur due to carbonation of concrete or attack by chlorides. Carbonation is caused by penetration of carbon dioxide into the concrete and reaction with alkaline calcium hydroxide which results in formation of calcium carbonate and water. Atmospheric carbon dioxide can only react with the cement hydrates when there is sufficient pore water to first dissolve it.[87]

Plate 4.25: The bases of columns

The rate of carbonation increases with temperature, carbon dioxide concentration and porosity.[88] The reduction of alkalinity of cement damages the passivating (protecting) layer on the surface of reinforcement bars and enables corrosion. Carbonation starts at the concrete surface and penetrates faster if the porosity of concrete is high and the atmospheric humidity is between 50% and 75%. Carbonation slightly increases compressive strength of concrete, but has a negative impact on the protection of the embedded reinforcing steel.[89] When

[85] Fadayomi, J., The Deterioration of Reinforced Concrete: An Introduction, in Macdonald, S., *Preserving Post-War Heritage: The Care and Conservation of Mid-Twentieth-Century Architecture,* English Heritage, 2001, p. 104.
[86] Ibidem, 105.
[87] Parrott, L. J., *A review of carbonation in reinforced concrete,* Cement and Concrete Association for Building Research Establishment, Garston 1987, p. 2.
[88] Ibidem, 3.
[89] Fadayomi, J., The Deterioration of Reinforced Concrete: An Introduction, in Macdonald, S., *Preserving Post-War Heritage: The Care and Conservation of Mid-Twentieth-Century Architecture,* English Heritage, 2001, 107.

the concrete becomes carbonated, it is likely that the steel surface will produce rust whose volume is ten times bigger than the steel it replaces, causing the cracking and spalling of the concrete cover.[90] The concrete condition survey should entail a careful cross-correlation of the results of a cover meter survey (to assess depth of cover of steel reinforcement) with the results of carbonation depth testing to enable accurate identification of all locations where reinforcing steel is actually in contact with carbonated concrete. If there is no reinforcing steel in the carbonation zone, there is no need for removing carbonated concrete.[91] Renders and tiles are more reliable than painted coatings in minimising the rate of carbonation.[92]

Chloride can also destroy the protective layer on reinforced concrete. Chlorides can remain on poorly washed sea-dredged aggregates, or could come from de-icing salts or from exposure to sea salt spray or sea water. The content of chloride ions in concrete below 0.2-0.4 % is considered safe, but above 1.0 % represents a high risk of corrosion. Surface-applied corrosion inhibitors are recommended when repairing listed structures as they penetrate concrete and act directly on the steel reinforcement to inhibit the corrosion process and may reduce the need for an overall coating treatment.[93]

The concrete itself can degrade due to sulphate and/or acid attacks. Aggregate can degrade due to alkali aggregate reaction (AAR) in which the alkali in cement reacts with the aggregate to produce an expansive gel that causes the concrete to crack, typically in three-legged crack form.[94]

The risk of corrosion is increased when the resistivity (a measure of resistance to the passage of current) of concrete is low. When the resistivity is high, > 12 kÛ cm, the resistance to current flow is high and the rate of corrosion is minimal, but if the resistivity is low, < 5 kÛ cm, a high rate of corrosion can occur.[95] As the relative humidity content of the concrete increases, its resistivity decreases.[96] If the relative humidity is below 60-70% RH, corrosion will not normally occur.[97] The risk of corrosion is also increased if the concrete exposed to atmosphere is subjected to cycles of wetting and drying.[98] The application of coatings and surface treatments can be highly effective in limiting or preventing degradation.[99]

The limitations of patch repairs, particularly with respect to chloride attack, have instigated the development of other approaches to repair.[100] As the corrosion of steel is an electromechanical process that results in the formation of anodic and cathodic sites on the surface of the steel, the metal is dissolved at the anodic side while the cathodic side remains unaffected. If

[90] Ibidem, 109.
[91] Ibidem, 110.
[92] Parrott, L. J., *A review of carbonation in reinforced concrete,* Cement and Concrete Association for Building Research Establishment, Garston 1987, p. 26.
[93] Ibidem, 113-114.
[94] Foster, A., Atkins, C. and Buckley, L., Preserving reinforced concrete, in Brebbia, C. A. (Ed.), *Structural Studies, Repairs and Maintenance of Heritage Architecture X,* WIT Press, Southampton, 2007, p. 365.
[95] Lambert, P. Repairing Reinforced Concrete: An Overview, in Macdonald, S., *Preserving Post-War Heritage: The Care and Conservation of Mid-Twentieth-Century Architecture,* English Heritage, 2001, p. 119.
[96] Ibidem.
[97] Ibidem.
[98] Ibidem.
[99] Ibidem.
[100] Ibidem, 121.

a small externally generated current is applied to the steel, all the steel can become cathodic and non-corroding.[101] As the design of cathodic system has to take into account many variables (e.g. the aggressiveness of the environment, the area of steel to be protected, the resistivity of the surrounding material, the positioning of any external metallic objects that could be affected by the system, and the type of anode used), it has been suggested that the initial design requirements and the application of a current throughout the service life of the structure can make cathodic protection more expensive and complex than other repair options.[102]

As the alkaline concrete environment that protects steel reinforcement can be changed by the acidic reaction with carbon dioxide (carbonation), the electrochemical technique of re-alkalization can be used to restore the alkaline environment.[103] Following the re-alkalization intervention, the concrete surface is coated with an anti-carbonation coating. The advantage of the technique is that the disruption can be kept to a minimum.[104] Chloride extraction is the electrochemical technique used for desalination of concrete.[105]

Water repellents based on organic silicon compounds are protective coatings that enhance durability of new and existing reinforced concrete structures without significantly altering the appearance of exposed concrete, which is of interest for repairs of listed structures.[106] Spray-applied cementitious materials with low resistivity are specified for use in major reinforced concrete repair programmes.[107]

A recently developed electro-osmosis system for controlling moisture levels in new and existing reinforced concrete structures is capable of reducing moisture levels in concrete to between 60% and 70% RH and maintaining this level independent of external weather conditions.[108]

Regarding listed structures of reinforced concrete, identification and eradication of the cause of the damage is crucial for long-term conservation.[109] However, there are still no unambiguous guidelines available on how to approach the investigation or repair of damaged reinforced concrete buildings, whether listed or not.[110] Historical information should be gathered on how and why a material is used, changes to the concrete, its environment and function during its history, changes in chloride levels, levels of carbonation and any changes in the chemical and physical characteristics.[111] Categorizing the problem (e.g. structural, durability, moisture, drainage, safety, social, cosmetic or aesthetic), establishing its cause, extent and likelihood of continuing, identifying effectiveness and side effects of previous repairs assist in directing the investigation process.[112] A thorough physical investigation should

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[101] Ibidem.
[102] Ibidem.
[103] Ibidem, 122.
[104] Ibidem.
[105] Ibidem.
[106] Ibidem, 123.
[107] Ibidem, 125.
[108] Ibidem.
[109] Davis, K. Conserving Concrete: Defining an Appropriate Approach for Listed Buildings, in Macdonald, S., *Preserving Post-War Heritage: The Care and Conservation of Mid-Twentieth-Century Architecture,* English Heritage, 2001, p. 129.
[110] Ibidem, p. 130.
[111] Ibidem.
[112] Ibidem, p. 131.

map defects such as spalling, delamination, cracking, depth of friable surface layers, and other defects to inform on the nature and extent of the problem.[113] The investigation should provide information on soundness of the building structure (including foundations and roof), the overall condition of the concrete, corrosion of steel, concrete degradation (e.g. caused by alkali-silica reaction, poor quality aggregate, poor compaction, low cement content or high water-cement ratio), coating degradation, effectiveness of drainage, and the problems associated with other building components (e.g. drainage pipes, gutters, balconies, chimneys, windows etc.).[114]

For listed buildings, English Heritage requires planning the test programme which should include visual assessment and, frequently, destructive testing to estimate compressive strength of core samples, chloride ion concentration levels in dust samples, depth of cover to steel reinforcement through calibrated cover meter survey, depth of carbonation through a simple, on-site chemical test, petrographic examination of core samples for visual inspection and determination of freeze-thaw and alkali-silica reaction.[115] The test sites should be representative but could be selected at discreet locations within a building without causing severe damage.[116] Reinstatement of the investigation holes might require the use of lime-based mortars rather than polymer modified proprietary repair mortars.[117]

Repair options should consider whether the most appropriate and practical technical solution will be used to reinstate the building strength, function and durability, and to allow appropriate maintenance.[118] The capital and life-cycle cost of the repair, the cost of disruption during the repair, and value added by the repair should be considered in the evaluation of economic aspects. Conservation aspects such as the use of original materials for repair and the retention of the original design and appearance should be considered for the repair of listed buildings. Social aspects such as health and safety requirements during the repair and the perception that the building will be improved in long-term by removing the cause of the problem through the repair should be considered.[119]

It has been suggested that it is unlikely that any one of repair options would be sufficient on its own and that the most appropriate would probably be a combination of more than one (Table 4.26).[120]

The above list is a useful exercise in decision making regarding the presented or any new repair methods which have been developed, particularly over the last decade, that can reinstate or enhance the durability and performance of existing reinforced concrete structure while allowing the original structure to remain relatively intact.[121]

Another tests were performed on reinforced concrete structure in April 2011 (See Chapter V).

113 Ibidem, p. 132.
114 Ibidem.
115 Ibidem, p. 133.
116 Ibidem.
117 Ibidem.
118 Ibidem, p. 134.
119 Ibidem, p. 135.
120 Ibidem.
121 Foster, A., Atkins, C. and Buckley, L., Preserving reinforced concrete, in Brebbia, C. A. (Ed.), *Structural Studies, Repairs and Maintenance of Heritage Architecture X,* WIT Press, Southampton, 2007, p. 371.

Repair Option		Anticipated maintenance-free service life	Advantages	Disadvantages	Level of intervention
1	No action (do nothing)	Less than five years	• cheapest short-term solution – no capital outlay • no access required, no pollution or disruption to site • no conservation problems	• deterioration will continue at accelerating rate • structure becomes unsightly and eventually structurally unsound, service life of structure will be limited • unlikely to be the most cost-effective long-term solution	None, but safety checks would be required.
2	Traditional repairs with no coating	At five-yearly intervals throughout the service life	• cost-effective short-term solution (repairs can be colour and texture matched) • minimal scaffolding/access required • minimal ongoing maintenance required • limited disruption to site	• will not prevent deterioration in the structure elsewhere • corrosion damage continues and further repairs will be required (in say five years) • may not provide the most cost-effective long-term solution	Not often if carried out correctly, but adjacent areas would need to be checked.
3	Traditional repairs with a coating	At five to ten-year intervals throughout the service life	As above	As above • almost all coatings will alter appearance • coating will not prevent ongoing corrosion if the carbonation has progressed to reinforcement level or if chloride levels are above threshold levels at reinforcement	As for 2 above, but also at end of coating service life (dependent on type of coating).
4	Traditional repairs followed by electro-chemical realkalization with no coating	Ten to twenty years	• one time fix solution • after application, no further maintenance or monitoring required • minimal alteration to appearance • well-documented and proven technology • can be most cost-effective long-term solution • process re-established corrosion protection properties of the concrete to protect steel reinforcement • minimizes amount of carbonated concrete to be removed	• repair mortar for patching must be compatible with realkalization process (limits manufacturers and products) • higher capital cots • carbonation and chloride ion ingress will recommence, albeit at a slower rate • fairly extensive clean-up operation required to remove materials used in realkalization process • some concretes may contain reactive aggregate (AAR), which needs to be determined prior to alkalization	At approximately ten-yearly intervals if carried out correctly

Table 4.26: Repair of fair-faced concrete building: balancing remedial options

(Adapted from Davis, K. Conserving Concrete: Defining an Appropriate Approach for Listed Buildings, in Macdonald, S., *Preserving Post-War Heritage: The Care and Conservation of Mid-Twentieth-Century Architecture*, English Heritage, 2001, p. 136-139.)

Table 4.26 2nd part

5	Traditional repairs followed by electro-chemical realkalization with coating	Twenty years	As above • extends maintenance-free life expectancy by retarding ingress • clear sealants will not alter visual appearance significantly • sealants will assist in binding friable surface material to increase durability	As above • higher capital cost than 1-4	At end of coating service life (dependent on type of coating).
6	Impressed current cathodic protection	Fifteen to twenty years plus, dependent on anode type	• minimizes amount of chloride contaminated or carbonated concrete to be removed • provides long-term corrosion protection id operated correctly (service life dependent on anode type) • should prevent further corrosion-related deterioration of structure	• higher capital cost • poor design of ICCP can significantly affect appearance • disruption to users • may require significant electrical continuity bonding of steel reinforcement • requires ongoing maintenance • requires permanent AC power supply • requires ongoing monitoring by specialist • requires specialist design • repair mortars must be compatible with ICCP system (limits products and manufacturers) • possible effects of stray current interference with other metallic components must be avoided • access to internal face of building may be required	Regular monitoring and maintenance. Requires degree of technical expertise.
7	Traditional repairs followed by corrosion-inhibiting coating or migrating inhibitors	Unknown (fifteen to twenty years)	• clear versions have minimal impact on appearance of structure • extends maintenance-free life by retarding ingress of corrosive ionic species and gases, and at the same time re-establishes corrosion protection properties of the concrete to protect reinforcement • minimizes the amount of carbonated but still sound concrete to be removed • minimal ongoing maintenance required • coating assists in binding friable surface layer to improve durability • could prove to be the most cost-effective option for some cases	• repair mortars must be compatible with inhibitors (limits products and manufacturers) • some concretes contain reactive aggregate (AAR), which needs to be determined prior to realkalization • no long-term data on performance available • performance claims have not yet been substantiated in practice • coating may detrimentally affect the re-application of the inhibitor	Routine inspection. Re-application after ten to fifteen years.

4.2.9 A proposal for restoration interventions

The following section indicates the actions for eliminating the causes of deterioration of reinforced concrete structure in Lion Chambers and proposes interventions that could increase the building sustainability. Water penetration into the basement has to be prevented. Excavation around the basement walls will enable inspection, installation of drainage next to the foot of the foundations and waterproofing of the external surfaces of the basement walls. As excavation around the building has to be undertaken, there is an opportunity to install a ground source heat pump before the excavated area is filled with soil. Internal thermal insulation of basement walls and floor would improve energy efficiency.

As the prism glass on T shaped iron beams along the top of the south basement wall were covered with asphalt, they need to be restored to provide natural light to the basement. The glass roof in the basement space connected with the adjacent building should be restored and protected from vandalism, e.g. by a strong steel net above the roof. Heat recovery mechanical ventilation could be installed in this area to provide continuous ventilation of the basement.

Waterproofing layers on the building roof need to be removed to inspect the roof surface and repair any damage. Thermal insulation on the external surface of the roof should be installed and protected before installing waterproofing materials. The lead cover of cupola should be removed and the cupola surface covered with thermal insulation which should be protected from water penetration before the new lead or aluminium cover is installed. If the cupola does not have thermal insulation, condensation could form on its internal surface in cold weather as warm internal air carries vapour up. On the inclined sections of roof, on the south side of north-facing roof windows, hot water solar panels could be installed to top up hot water obtained from a ground source heat pump for heating. These roof surfaces cannot be seen from the street level.

Water collection from the roof could be considered by installing a water tank which might be placed within the space which also houses the elevator mechanism at roof level.

As suggested in previous building survey reports, the building structure should be dried before any repair work on its surfaces is undertaken.

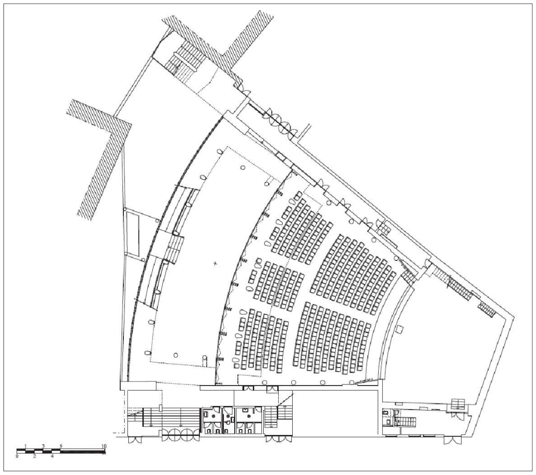
Along with natural ventilation, mechanical heat recovery ventilation should be provided in rooms that do not have windows.

In order to prevent condensation on internal surfaces of the external walls, an appropriate thermal insulation should be installed. As the aim of the restoration of elevations is to preserve and restore the original appearance as much as possible, consideration should be given to thermal insulation materials which have high insulating properties and low thickness, and renders with thermal insulation properties.

Windows with high thermal insulation properties, high airtightness and adequate appearance (e.g. double glazed windows with narrow space between the glass panes) should be considered. As the evidence on the shape and design of the original windows is available from old photographs, they can be restored.

Research on the interior design should be undertaken to preserve original details such as the bright green wall tiles in the entrance hall and other details that can be preserved during the adaptation for new use. High quality inte-

Plate 4.26: Plan of Theatre Duni



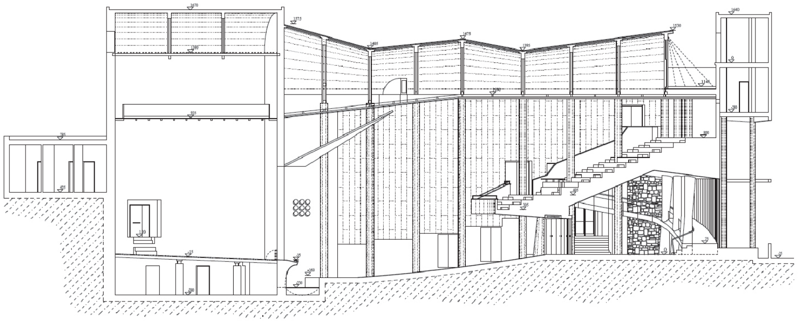


Plate 4.26: Longitudinal section of Theatre Duni

rior design that respects the simplicity of the original design should be undertaken.

4.3 **The Duni Theatre - Matera (Italy)**

4.3.1 Social and cultural context[122]

Right after the war, the town of Matera went through a period in which it really aspired to modernize and evolve itself towards more civil living conditions. In this context, two private citizens, the typographer and editor Cav. Carlo Conti and the lawyer Domenico Latronico, comissioned a young Materan architect, Ettore Stella (see Chapter II), in the summer of 1946, to realise the project for a cinema-theatre with adjoining hotel, to be situated in the downtown area of the city, between via Roma and the back of the 18th century via Lucana.

The Duni Theatre was the first public work designed by Stella and it was done with enthusiasm for his town. This was the first work built entirely in reinforced concrete in Matera. The young architect was aware of the construction difficulties with this new material, above all for the Materan workers who, although experts in working with tufa, had little or no experience working with reinforced concrete. With the realisation of the Duni Theatre, a decisive change was made regarding the public architecture of the city; through all of this, from economic investments, the choice of the planner, the application of new bulding techniques, to the use of materials and the availability of local workers, a new cultural condition for the city was created.

The project (Plate 4.26, 4.27), ambitiously conceived as a cinema-theatre with adjoining hotel, was presented in August of 1946 for approval to the Municipal Building Commission.

The detailed project was drawn-up between October 1946 and February 1947, in collaboration with the Materan architect Salvatore Masciandaro. Construction began in the spring of 1947 under the direction of Stella and the engineer Vigliar, who was commissioned to work on the project and to do structural calculations. The construction was entrusted to the Materan enterprise of the Morelli Brothers. The building pro-

[122] See Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare"*, Edizioni Librìa, Melfi, 1999, pp. 25-27.

ceeded splendidly up to its completion in November 1948. In March of 1949 the cinema-theatre obtained the license to operate and was named after the illustrious Materan composer, Egidio Romualdo Duni (Matera, 1708 – Paris, 1775).

4.3.2 Stella's project[123]

The project drawn-up by Stella was a complex architectural organism, where, in addition to the theatre, other rooms and services were planned. The theatre was interpreted for the first time as a "place" for shows.
The site chosen for the construction of the cine-theatre, was surrounded by pre-existing buildings, which made the design of the facades impossible, or at least difficult, given that they would be hidden by the surrounding buildings.
To overcome this limitation, Stella channelled his creative inspiration into the building's interior, not being able to express his creativity with regards to the exterior. It is here that the idea was born to connect the two entrances located on opposite streets, creating a long, arched lobby in glass, presenting itself as a real urban gallery, with an attractive, spatial effect.
Altogether, the project provided for a theatre with 1049 seats[124] (Plate 4.28, 4.29), divided into stalls and balcony; the cash register was placed in the centre of the large foyer, where the doors open at the back of the stalls. This planning solution allowed the use of the entrance hall as a grand "foyer" for the theatre spectators and created a special unity between the theatre and the lobby.

Plate 4.28: Details of balcony seats (Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

Plate 4.29: Details of balcony and stalls of theatre (Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

[123] See Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare",* Edizioni Librìa, Melfi, 1999, pp. 28-48.
[124] Between 1992 and 1995, a series of projects and trials were prepared to bring facilities in line with the new safety standards for public venues. For safety reasons, it was envisaged to reduce the number of seats: in the stalls from 520 to 489 and in the gallery from 529 to 499.

Plate 4.30: Detail of lobby (Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

There are two ramps facing each other, which lead from the lobby (Plate 4.30) to the balcony at the extreme ends of a corridor which divides the balcony into two sections: the upper and lower balcony, looking out over the stalls.

The structure was built entirely of reinforced concrete; the ground conditions (an area of clay sediment and a water table) requiring the structural engineer to opt for a foundation of reinforced concrete inversed beams. The concrete was prepared on site combining the cement, coming from Bari, together with the iron for the reinforcement bars, sand from the Bradano river and rubble from local quarries. The perimeter walls of solid brick, about 50 cm thick, are fire resistant and run independently of the supporting structure which is built from long, visible, circular-sectioned columns and cast square-sectioned beams in reinforced cement. The stage is enclosed in a self-supporting tufa wall, 80 cm thick.

The mixed-structure lofts are built from concrete beams and perforated bricks. The internal vault surface is finished off with a single layer of plaster, while the external vault surface is finished off with different materials such as marble and tiles, depending on the destined use of each space.

The architect Stella entrusted the formal expression of the space to structural elements, placing the tall, visible, circular columns in the theatre, free from the perimeter walls.

The bold, curvilinear embossing of the galleria was emphasized, molding (with a cross-section which is gradually reduced from the floor to the mid-height and then expanded towards the top of the column) the columns of the lobby according to the force of the stress to which they are subject.

The balcony is supported by two orders of columns arranged parallelly in the stalls and in the lobby, and cantilevered over the stalls for about 3 meters.

Together with these elements which characterise the spatial and architectural configuration, the technological aspects of the work, related to lighting and acoustics, should not be considered of secondary importance, for example, regarding the avoidance of distortion and the concentration of sound.

The columns finish is "fired stucco"[125] (The stucco or "fired" mixture, was a paste of Greek tar, yellow wax and turpentine with marble dust, used to fill in the pores of the travertine and to join the ashlar stone). The ramps are covered in linoleum

[125] Baldinucci F., "Vocabolario toscano dell'arte del disegno", Firenze 1681.

(green lining produced by Pirelli), with glass parapets. White, veined marble from Carrara was used on the walls of the back of the lobby. Maple handrails, glass windows looking onto the garden, the local limestone on the rustic walls, the natural oak of the doors and windows, give the building the organic beauty of a deliberately "modern" work. The characteristic signs of Modern architecture within the 20th century Italian panorama, can be immediately recognized in E. Stella's work.

4.3.3 Interventions during the building life[126]

In order to ensure health and safety in public venues, in 1951 the Ministry of Domestic Affairs called for sweeping measures to check all the cinemas built after the war. Although the Theatre had been opened to the public, it did not have emergency exits. In May of 1951, the Provincial Fire Commission for public venues prescribed an adaptation of the cinema in order to meet the new safety norms, requesting the creation of emergency exits.
Additional interventions were carried out in 1955, with the first modification of the stage system: due to the introduction of widescreen movies, the proscenium had to be enlarged, tearing down the two lateral, oblique walls and rebuilding them with a minor inclination.
New interventions and modifications were carried out between 1977 and 1978, when the old, plywood seats and the cash register were replaced; the part of the lobby accessed from via Lucana was completed; the stairs of the balcony were enlarged and the theatre floor carpeted. The textile-covered railings along the ramps and on the balcony were also eliminated and the concrete-framed glass wall that gives onto via Roma was completely replaced. The new position of the ticket-booth was also among the functional modifications planned in comparison to the original floor plan. Initially, the cash-register was located on the external facade that gives onto via Roma, with an opening that is still visible today. Instead, the architect Stella designed a new, provisional, folding booth to be fixed to the rough, internal wall on the side of via Roma, but this too, like the central cash-register, was never built.
The cash-register was finally placed inside the lobby, but in 1978 was again replaced by that which still stands today. It was built based on the design of Gregorio Padula who, together with his brother, would eventually design and carry out the work on the furnishings and finishes of the cinema-theatre.
Between 1992 and 1995 a series of plans was made and tests were run to bring the systems up to date with the new health and safety norms for public venues. For safety reasons, a reduction in the number of seats was planned: in the stalls from 520 to 489 and in the gallery from 529 to 499. In 1995 the structural stability of the building was certified by the engineer Cocca and new toilets were built in the balcony, in addition to new changing rooms and toilets near the stalls, as well as fixing the metal handrails on the balcony. Also in 1995, the glass windows of the entrance on via Roma were replaced with new panels of beech plywood. At the same time, an accessible toilet for people with disabilities was installed and the window that looks out onto the garden was renovated.

[126] See Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare",* Edizioni Librìa, Melfi, 1999, pp. 55-61.

Plate 4.31: Front of Theatre Duni (Via Roma)

Plate 4.32: Front of Theatre Duni (Via Lucana)

4.3.4 Assessing the current condition

Currently, the Duni Theatre functions both as a cinema and theatre, being the only one of its kind in the town of Matera. Ownership has changed over time; today, it is only thanks to the strong will of the owners and managers that this "representative example of modern architecture" is allowed to thrive, despite the economic difficulties regarding maintenance and management costs.

The Duni Cine-Theatre still preserves the distinctive features of Stella´s original project: broad storm windows placed both on via Roma (Plate 4.31) and via Lucana (plate 4.32), which give way to an area that serves as the theatre's foyer; a ticket-booth counter near the entrance on via Roma; and an information bulletin-board, encased in the wall and protected by sliding glass doors.

There is also a low-lying, timber furnishing (a flower box) across the foyer, separating the ticket area from the lobby (Plate 4.33). A folding timber screen separates the entrance hall from the stalls, that can be completely opened, which – as mentioned earlier – serves to unite the lobby with the theatre to form a grand foyer for the occasion of theatrical productions. The lobby is paved in even, white, veined marble slabs and recurring bardiglio (grey) marble, 2 cm thick. The sequence of panels/doors, which can be opened, is certainly one of the notable "innovations"of the original project from 1946.

Two progressively curvilinear ramps, located opposite each other, lead from the lobby to the overhanging balcony, with an approximate 12% gradient (Plate 4.34), along large glass windows that look out onto the adjacent garden. The parapets have maplewood handrails,

mounted on metal profiles, and tempered, glass panes.
The particularly shaped columns of the lobby, as will be discussed later, have been treated with "fired stucco" (see Chapter V). However, it is the shape of these columns, tapered in at mid-height and slightly inclined, which give the central area of the entrance an unimaginable spaciousness compared to the previous structures. Finally, it is the materials used, the wood and glass, which render this architecture both "ethereal and majestic" at the same time.
The entrance floor on via Roma is 20 cm higher than the street level. It is a wide opening with three doors and double storm windows, surmounted by a transparent window next to a glass brick wall from the floor to the ceiling The typology and design of these elements denote an attention to detail, such that they remain a beautiful example of interior design even today. However, the entrance level on via Lucana is 1.30 m above the foyer floor. It also has three double doors, all recently equipped with anti-panic door handles.
To the right of the entrance, there is a corridor to the toilets and changing rooms. On the left, there is an emergency staircase that leads down from the balcony. The foyer ceiling consist of moulded and plastered shapes that conceal the articulated, load-bearing structure of the balcony.
The grandeur of the spaces and walkways, thoughtfully planned, should remind us of the multi- functional use that the original project envisaged, which also included a hotel that was never realised. The theatre is a large, trapezoid-shaped space which includes the stalls, the balcony and the stage. The lower part of the walls, up to 2.0/2.5 m, is covered in a fireproof, beechwood paneling. The stalls have an inclined floor which begins at the level of the foyer and descends towards the orchestra pit, in front of the stage. Two oblique walls and an inclined, suspended ceiling define the proscenium.
Due to wear and tear, these finishes and soundproofing technical elements are not any more adequate for their proper function.

Plate 4.33: Details of lobby and ramps

Plate 4.34: Details of ramps and glass wall and parapets

The stage base is a robust perimeter wall in tufa that separates it from the proscenium. Timber boards cover the stage floor, while the ceiling consists of a timber, lattice-work structure for suspending stage props.
The projection booth, built after the construction of the cinema, is positioned at the level of the upper balcony and supported by four columns based in the garden area at the back of the theatre. The projection booth has a single room, containing a projector, and an identical overhead space used for storage. This contemporary technological intervention perhaps shows, on the one hand, the necessity to furnish the structure with new projectors and, on the other hand, an incapacity, often present, to have the same design capabilities and to achieve a "design unity" as the designer of the original project.
The areas that are not part of the Cinema-Theatre building and that do not belong to the owner are those in front of the entrance to the Cinema on via Roma (or better known as the "Private Duni Road") and the internal garden, neighboring the voluminous apse of the Church of San Francesco da Paola and creating a nice patio that lights up the lobby.
Today, we can still enjoy this thoughtfully planned and well built architecture, but the definition of "architecture to be safeguarded and preserved" shows us the fragile face of a "monument" as of yet undeclared, but certainly already "proclaimed" by Italian artistic and cultural sensibility.

5.1 **The Lion Chambers - Glasgow (UK)**

5.1.1 The technological and structural system

With the advent of the Second Industrial Revolution the international economic system radically changed due to the introduction of new materials, technologies and techniques in construction. Within this context, the introduction of reinforced concrete was highly important for the building construction. Initially, the use of this new material was mainly associated with industrial buildings, civil construction works and infrastructures; apart from a few pioneering concrete buildings for housing in the 19th century, it was used for residential buildings more frequently from the start of the 20th century.

One of the principal characteristics that influenced the use of this material was its fire resistance; that is a significant characteristic for the premises of small businesses and the infrastructure, other than industry, i.e. in the environments that are more vulnerable to fire because of the activities that take place and/or because of the materials stored in them.[1] From this first, although general, consideration, more precise analysis of the characteristics of this new material and the related structural systems highlighted the advantages that it entailed in relation to the building production process; among them the monolithic nature of the structure (useful for better stability against, above all, dynamic actions), a versatility of forms generated from this material, the easiness of construction linked to the undisputed economic advantages related mainly to the decrease of transportation cost and to the reduction of the quantity of metalwork in relation to the civil engineering works at the start of 20th century (e.g. Eiffel and others).

One of the people who gave a notable impulse to the development and spread of this new material was François Hennebique (Neuville-Saint-Vaast, 26 April 1842 – Paris, 7 March 1921), a formidable personality of the French engineering who took a patent for reinforced concrete in 1892[2], after having seen reinforced concrete containers manufactured by Joseph Monier at the International Exhibition in Paris in 1867. Hennebique introduced a new construction system that united the resistance and compression characteristics of concrete with the capability of steel to resist tensile forces by optimising the placement of bars within the concrete components (similarly to the braces, the lower bars are folded at 45° and extended to the upper bars of a beam where the

[1] See Abrate M., *"Una interpretazione dello sviluppo industriale torinese",* in "Torino città viva, da capitale a metropoli 1880 – 1980", Centro Studi Piemontesi, Torino, 1980, vol. I.

[2] Hennebique was acknowledged as the inventor of reinforced concrete although 10 years after the invention was briefly accredited to Joseph Monier since 1878. Hennebique become more famous because he licensed his system and therefore took care of the quality control which reassured the clients and enabled him to build more reinforced concrete buildings than anyone else at that time.

inversion of moment occurs). Hennebique's system (Plate 5.1)[3], therefore, allows the complete construction of a load¬-bearing structure of reinforced concrete which includes the foundation (footings or inverted beams or slabs), columns, principal beams, secondary beams and slabs; columns (square, rectangular or polygonal sections) and beams envisaging even the introduction of a new element[4] in the system of longitudinally placed bars: stirrups (the twin vertical braces made of iron whose function was to hinder diagonal forces in a bending component). A further new component of Hennebique's construction system is the idea of lightening the horizontal structure while ensuring the optimal static performance.[5] These structural formulations were applied in numerous public and residential buildings from the last decade of the 19th century and during the first two decades of the 20th century.

The realised buildings are very diverse: from the Parisian Refinery in Saint-Ouen (Paris, France, 1894) to the Weavers Mill (Swansea, Walles, UK, 1897), the Dunston Grain Silos (Dunston-On-Tyne, UK, 1902), and the large infrastructures such as the Tweed Bridge (Berwick upon Tweed, UK, 1928).[6] Among these industrial and public structures, following the above developments in reinforced concrete, a series of splendid residential buildings appeared such as the Lion Chambers in 172 Hope Street in Glasgow, UK[7] (Plate 5.2). As mentioned in the previous chapter, it was built in 1904-07 and designed by the architects J. Salmon Jr and J. Gillespie; this building is considered as one of "the first examples of good practice in architecture built with cement and steel"[8]. It consists of nine levels, including the attic and the basement. It was built only with manual labour (i.e. without the assistance of any particular machinery) by local workers under the supervision of a contractor licensed by Hennebique.[9]

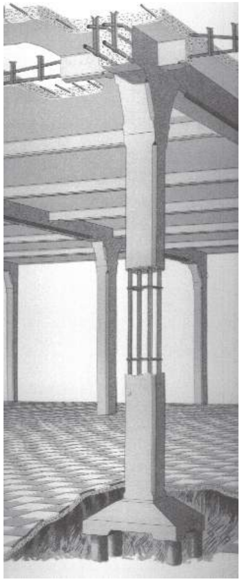


Plate 5.1: Hennebique´s construction system

Plate 5.2: 172 Hope Street, Glasgow

[3] See http://www.sacs.it/tesi/c004.htm#4.22
[4] Donghi D., *Manuale dell'Architetto, vol. I,* UTET, Torino, 1905, p. 395.
[5] Nelva R., Signorelli B., *"Caratterizzazioni del cemento armato sistema Hennebique in Lombardia agli inizi del XX secolo",* in *"Nuova Edilizia Lombarda"* n. 12, December 1977
[6] McBeth D., "François Hennebique (1842-1921), reinforced concrete pioneer", in Civil Engineering, 1998, n. 126, May, 86-95, paper 11382 – 15th August 1998.
[7] Cusak P., *"François Hennebique – the specialist organisation 1892/1909",* in proceedings of the "Newcomen Society", 1954-1985, n. 50.
[8] *"Structures and Buildings, Historic Concrete",* in Proceedings of the Institution of Civil Engineers, August/November 1996.
[9] *"A Reinforced Concrete Office Building",* in The Builders Journal and Architectural Engineer, January 1907.

Plate 5.3: Reinforced concrete cupola

Vertical communication is provided by a staircase from the ground floor to the attic and by a lift (one of the first installed in Scottish cities, following their introduction in the USA for which Glasgow was the main harbour for commercial activities with Europe).

As mentioned, the load-bearing structure was built using Hennebique´s construction system. It has 21 columns – along the external perimeter and within the building – which rise from the basement to the last level, narrowing at each successive level, consistent to the decrease of the load that they support.[10] The structural stability, already guaranteed by the use of a monolithic reinforced concrete structure, is further strengthened through the extensive use of secondary beams according to the typical detailing of Hennebique´s structural system.

The composition of material is characteristic to the Hennebique´s system[11], i.e. the mixture of cement/send/aggregate was planned as 1/2/4. The external walls were built of prefabricated concrete panels in various sizes whose thickness is around 10 cm. Glass surfaces are widespread (as typical for the facades built of panels); this is especially notable on the North front (the elevation to Bath Lane) and on the large part of the main elevation to Hope Street (West front). The façade finish is a cement-based plaster. An octagonal cupola (entirely made of reinforced concrete) completes the top of the building corner tower (Plate 5.3).

5.1.2 The previous diagnostic investigations

A thorough investigation campaign,[12] undertaken between 1989 and 1991, pointed out that the condition of the entire building was fairly satisfactory, notwithstanding the presence of pathological phenomena that were also evident (mostly related to the quality of the material), but, however, linked to the natural aging processes of the material, although catalysed by the presence of humidity due to rain penetration or environmental conditions[13] developed within the building which then led to its abandonment.

[10] Clark C., Capeling G., *"Feasibility study for the Conservation of Lion Chambers, 170 Hope Street, Glasgow",* completed for Historic Scotland, February 2001, p. 27.
[11] *"Structures and Buildings, Historic Concrete",* in Proceedings of the Institution of Civil Engineers, August/November 1996.
[12] Clark C., Capeling G., *"Feasibility study for the Conservation of Lion Chambers, 170 Hope Street, Glasgow",* realized for Historic Scotland, February 2001.
[13] Ibidem, p. 35.

The small fissures on the external surfaces and the crumbling of the covering layer enabled the rainwater to come into contact with the reinforced concrete and to develop a very humid internal microclimate, causing either carbonation of the surface (the depth of carbonation is from 2 mm to 150 mm)[14] or corrosion of the bars close to the surface, and in some cases the expulsion of the layer that covers the bars[15] (the cover thickness from 0 mm to 58 mm was determined through an electromagnetic introspection test[16] - BS 1881: Part 204: 1988).[17]
Therefore, a very small thickness of the reinforcement cover and the very humid conditions of the indoor environment are concomitant causes which have catalysed the spread of pathological phenomena in the reinforced concrete, which, however – considering the age of the material – has responded in a satisfactory way to the aggressive agents, also due to the great care in realising the construction details.[18]
A later study, this time on the petrographic characteristics of the conglomerate, completed on this building in August 2000[19], provides a series of useful indications for the interpretation of the results of sclerometric and ultrasonic tests that have been undertaken. The results can be systemised in the following way:

- Consistency of the large aggregate pieces: gabbro and basalt
- Consistency of the fine aggregate pieces: siliceous sand
- Bounding medium: Portland cement (32.2% - 34.4%);
- Presence of voids: 1% -1.5%;
- Relationship water/cement (W/C); 0.6;
- Very high porosity (due to the W/C contents)
- Density of aggregates: 2750 kg/mc (65% 66.8%);
- Density of bounding medium: 3140 kg/mc;

This diagnostic campaign was not followed by planning of the preservation interventions.

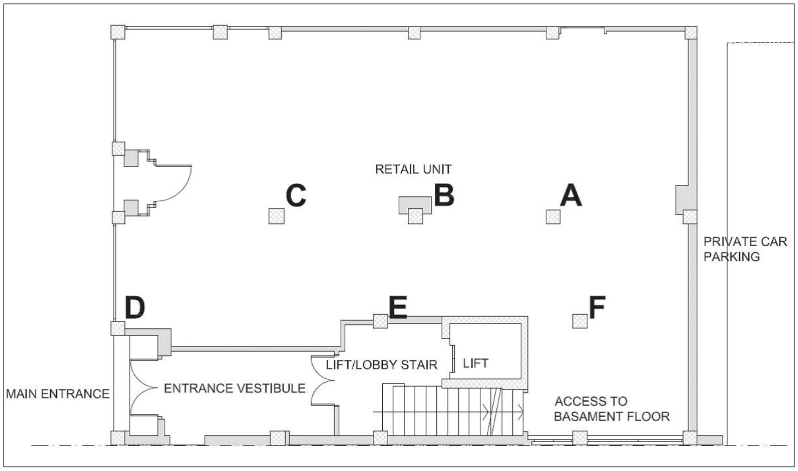
5.1.3 On site tests: formulation

Essential elements for the organisation of an investigation campaign are the selection of the components that will be examined (which have to be representative of the whole structure), the investigation methodology that will be used, and the number and location of the investigation points; these requirements, in fact, are fundamental to guarantee a certain level of "reliability" of the obtained results and a "trustworthiness" with regard to the qualitative indications related to the characteristics of the material. In the case of the Lion Chambers, the identification of the components to be investigated was made by selecting the structural components which make the internal core of the load-bearing structure for two reasons: (1) because they enable to investigate a concrete in the state of "natural aging" (i.e. without considering the aggressive atmospheric agents which could have modified the condition of the material) and (2) for easiness of selecting the te-

[14] Ibidem, p. 11.
[15] Ibidem, pp. 4-5.
[16] Ibidem, p. 11.
[17] Ibidem, p. 6.
[18] Ibidem, p. 31
[19] Eden A., *"Report on the petrographic analysis of three concrete cores ref CB/1, C3/4 and C6/1"*- Reference 5100, 23 August 2000 for GEOMATERIALS RESEARCH SERVICES LTD.

sting points. The structure of the whole building consists of a dual typology of structural components: those inserted in the external fabric (therefore difficult to investigate) and those located within the building (in most cases with the four sides of the components free of the contact with the façade and/or furnishings).
The selection of the location of the investigation points was random (with the aim to guarantee the representativeness of the investigation for the entire structure); in addition, "homogenous" areas[20] (which have the same characteristics) were noted and considered by making the obtained results "qualitative" and representative for all the components that show the same characteristics; a further condition is that the selected surfaces do not show any obvious condition of degradation. The methodology used to undertake the tests was exclusively selected in terms of the possibility to undertake the tests. Regarding the sclerometric tests, they were undertaken by placing the instrument always orthogonally in relation to the investigated surface. However, for the ultrasound tests, although the preference was given to the direct method of investigation (see Chapter III), sometimes the semi-direct and/or indirect methods were used because of (1) the desire to completely eliminate the "invasivity" of the test (avoiding even a minimal possibility of damage, even of aesthetic and/or superficial nature); (2) the difficulty to select corresponding points on the diametrically opposite part of the investigated component – because, for example, of the geometry or the size of a component; and (3) because of the presence of fixed timber furnishings which have prevented the access to the whole surface of the investigated component. The considered reference[21] (in terms of the number of tests with the aim to guarantee the reliability of the results) for the investigation campaign was taken from the framework of the Italian investigation procedures.

Plate 5.4: Selection of the columns for undertaking the tests – Ground floor



5.1.4 On site tests: analysis and results

The tests were undertaken within a week in April 2011 (external temperature 7-15 °C and humidity 65-87%). For each test ten values were taken, from which the average value was considered as illustrative.
The objective of the tests is to verify the state of consistency of the building's structural components with the aim to assess (although in qualitative terms) the resistance.

[20] Masi A., *"La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive".* Il Giornale delle Prove non Distruttive Monitoraggio Diagonstica, n. 1, 2005, pp. 2-3.
[21] See OPCM 3274/2005, Ordinanza del Presidente del Consiglio dei Ministri, 20 March 2003, *"Primi elementi in materia di criteri generali per la classificazione sismica del territorio nazionale e di normative tecniche per le costruzioni in zona sismica",* revised by Gruppo di Lavoro Istituito dal Dipartimento di Protezione Civile.

After having calibrated the instruments (using an anvil for the sclerometer and the testing sample for the ultrasound tests – see Chapter III), three different areas were selected for each investigated component (Plate 5.4); at 0.50 m (Table A), at 1.00 m (Table B) and at 1.50 m (Table C) from the floor. This selection, in fact, was motivated by the need to investigate the columns at the points of major stress (base and middle), having assumed (1) an uniform distribution of the loads and imposed loads (due to the homogenous structure) and (2) a homogenous condition of the loads (there are no visible cracks to induce any different considerations).

Table A: Elevation from the floor [50 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pb_A	37,75	3070,8	**15**
Pb_B	39,7	3046,05	**15**
Pb_C	38,1	3128,05	**16**
Pb_D	38,75	3147,35	**16**
Pb_E	39,95	3123,5	**16**
Pb_F	38,85	3110,05	**16**
Pg_A	37,75	3140,5	**16**
Pg_B	38,8	3163,8	**16**
Pg_C	38,55	3083,35	**15**
Pg_D	37,9	3097,05	**15**
Pg_E	40,55	3111,75	**17**
Pg_F	38,7	3111,9	**16**
P1_A	39,9	3168,3	**17**
P1_B	38,4	3165	**16**
P1_C	41,3	3163,9	**18**
P1_D	39,7	2920,8	**15**
P1_E	40,55	3036,2	**16**
P1_F	42,1	3187,6	**19**
P2_A	39,1	3048,05	**15**
P2_B	38,65	3044,15	**15**
P2_C	39,25	3153,3	**16**
P2_D	37,5	3154	**16**
P2_E	38,55	2978,5	**14**
P2_F	39,3	2978,5	**15**

Table A 2nd part: Elevation from the floor [50 cm]

P3_A	37,65	3069,175	**15**
P3_B	37,95	3076,75	**15**
P3_C	38,25	3017,8	**14**
P3_D	40,5	3101,375	**16**
P3_E	38,7	3037,65	**15**
P3_F	38,05	2978,5	**14**
P4_A	38,2	3086,65	**15**
P4_B	40,15	3085,4	**16**
P4_C	38,05	3103,25	**15**
P4_D	40,05	3111,5	**16**
P4_E	38,4	3141,05	**16**
P4_F	37,85	3097,4	**15**
P5_A	39,2	3115	**16**
P5_B	38,8	3060,95	**15**
P5_C	39,8	3101,2	**16**
P5_D	39	3101,95	**16**
P5_E	39	3109,6	**16**
P5_F	38,65	3045,6	**15**
P6_A	38,8	3093,3	**15**
P6_B	40,6	3106	**17**
P6_C	38,3	3144,45	**16**
P6_D	40	3130	**17**
P6_E	39,45	3113,8	**16**
P6_F	38,85	3084,7	**15**
P7_A	37,35	3180,05	**16**
P7_B	38,35	3167,65	**16**
P7_C	39,35	3172,35	**17**
P7_D	40,35	3160,05	**17**
P7_E	41,35	3054,5	**16**
P7_F	42,35	3113,85	**17**

Table B: Elevation from the floor [100 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pb_A	40	3034,15	**15**
Pb_B	37,7	3046,05	**14**
Pb_C	38,7	3128,05	**16**
Pb_D	39,7	3070,1	**16**
Pb_E	40,7	3054,55	**16**
Pb_F	41,7	2978,35	**16**
Pg_A	37,5	3084,25	**15**
Pg_B	38,25	3085,75	**15**
Pg_C	37,85	3043,1	**14**
Pg_D	38,05	3043,55	**14**
Pg_E	38,35	3041,2	**14**
Pg_F	38,35	3039,25	**14**
P1_A	39,9	3160,85	**17**
P1_B	38,4	3171,95	**16**
P1_C	41,3	3164,4	**18**
P1_D	39,7	3172,45	**17**
P1_E	40,55	3157,85	**17**
P1_F	42,1	3155,6	**18**
P2_A	45,85	3158,35	**20**
P2_B	44,94	3169,9	**20**
P2_C	47,11	3175,85	**22**
P2_D	45,62	3159,65	**20**
P2_E	45,48	3172,5	**20**
P2_F	47,38	3154,35	**22**
P3_A	39,7	3191	**17**
P3_B	39,7	3177,65	**17**
P3_C	39,8	3170,7	**17**
P3_D	37,5	3181,8	**16**
P3_E	39,7	3187,85	**17**
P3_F	39	3183,8	**17**

Table B 2nd part: Elevation from the floor [100 cm]

P4_A	39	3181,85	**16**
P4_B	39,4	3186,7	**17**
P4_C	40,1	3191,65	**17**
P4_D	38,9	3186,3	**17**
P4_E	39,3	3168,55	**16**
P4_F	38,7	3163,7	**16**
P5_A	39,2	3181,1	**17**
P5_B	38,8	3190,3	**17**
P5_C	39,8	3189,95	**17**
P5_D	39	3187,6	**17**
P5_E	39	3190	**17**
P5_F	38,65	3189,65	**16**
P6_A	38,8	3188,95	**17**
P6_B	39,8	3189,95	**17**
P6_C	40,8	3190,95	**18**
P6_D	41,8	3191,95	**18**
P6_E	42,8	3192,95	**19**
P6_F	43,8	3193,95	**20**
P7_A	37,35	3180,75	**15**
P7_B	38,2	3183,75	**16**
P7_C	38,1	3182,55	**16**
P7_D	39,25	3182,05	**17**
P7_E	37,9	3186,2	**16**
P7_F	38,95	3183,35	**17**

Table C: Elevation from the floor [150 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pb_A	38,5	3031,2	**15**
Pb_B	39,05	3044,45	**15**
Pb_C	39,3	3139,2	**16**
Pb_D	39,6	3116	**16**
Pb_E	39,3	2987,95	**15**
Pb_F	38,55	3059,275	**15**
Pg_A	39,3	3094,85	**16**
Pg_B	39,7	3103,3	**16**
Pg_C	39,6	3143,6	**17**
Pg_D	38,55	3010	**14**
Pg_E	40	3045,65	**15**
Pg_F	39,1	3111,75	**16**
P1_A	40,65	3157,55	**17**
P1_B	40,35	3170,25	**17**
P1_C	41,6	3166,55	**18**
P1_D	39,05	3046,6	**15**
P1_E	38,7	3101,3	**15**
P1_F	38,8	3172,5	**17**
P2_A	42	3031,2	**16**
P2_B	40,5	3044,45	**16**
P2_C	41,35	3139,2	**17**
P2_D	38,9	3116	**16**
P2_E	39,4	2987,95	**15**
P2_F	39,2	3036,05	**15**
P3_A	38,65	3024,375	**14**
P3_B	39,7	3019,7	**15**
P3_C	39,65	3076,95	**15**
P3_D	38,7	3130,4	**16**
P3_E	40	3005,85	**15**
P3_F	39	2920,8	**14**

Table C 2nd part: Elevation from the floor [150 cm]

P4_A	40,45	3087,2	**16**
P4_B	37,75	3101,75	**15**
P4_C	39,65	3125,45	**16**
P4_D	37,6	3126	**15**
P4_E	40,35	3093,4	**16**
P4_F	39,2	2980,9	**14**
P5_A	40,4	3080,6	**16**
P5_B	38,1	3048,9	**14**
P5_C	40,05	3143,95	**17**
P5_D	38,45	3164,15	**16**
P5_E	40,5	3056,35	**16**
P5_F	40,6	3110,2	**17**
P6_A	38,75	3080,6	**15**
P6_B	39,75	3048,9	**15**
P6_C	40,75	3143,95	**17**
P6_D	41,75	3164,15	**18**
P6_E	42,75	3056,35	**17**
P6_F	43,75	3110,2	**18**
P7_A	39,7	3180,05	**17**
P7_B	37,4	3167,65	**15**
P7_C	37,75	3172,35	**16**
P7_D	40,35	3160,05	**17**
P7_E	40,15	3054,5	**16**
P7_F	38,55	3113,85	**15**

The obtained results show a significant homogeneity of values measured at each investigated level; more precisely, the sclerometric tests show an average value (of the ten measurements made at each point) of the bounce index between 37.35 and 47.38, uniformly distributed on the surfaces (i.e. independently of the level at which the investigation was done); whereas, the ultrasound tests returned average values of the ultrasound between a minimum value of 2920.8 m/s^2 and a maximum value of 3191.65 m/s^2. Comparing the results by using the method SonReb (see Chapter III), the obtained values of the concrete resistance are from a minimum value of 14 MPa to a maximum value of 22 MPa.

5.2 **The Duni Theatre - Matera (Italy)**

5.2.1 The technological and construction system

Immediately after the Second World War, a great aspiration for modernising and evolving towards more civil conditions of life was felt in the town of Matera.[22] Economic measures and public works, initiated from 1946, to remedy a difficult economic crisis activated new developments after the construction stagnation during the war. The Duni Theatre (designed in 1946 by the Materan architect Ettore Stella) is among the first public buildings in the town after the Second World War.

The young architect was aware of the difficulties in building with this new material; thus, he resorted – very frequently during the construction of Duni – to inviting the workers from Northern Italy who were already experienced in the use of reinforced concrete.

Overall, the project envisaged an auditorium with 1,049 seats in the stalls and on the gallery.[23] The building is accessed through two different entrances located in two of the principal streets: one in Lucana Street (which is the town's 18th century throughway that connects the North and the South of Matera behind the ancient Rock Quarters and the other one in Roma Street, an old road that leads to the town's main square, Piazza Vittorio Veneto). Due to this peculiar location, the building, also embedded in the urban fabric of the historical centre, does not expose its facades completely free and independently from the context. The front to Lucana Street (part of which Stella planned as a hotel), is covered by white, vertical limestone slabs interrupted by the bare reinforced concrete columns. The front to Roma Street has a broad passage consisting of three doors and double frames, surmounted by a glass window and surrounded by a full-height glass brick wall.[24]

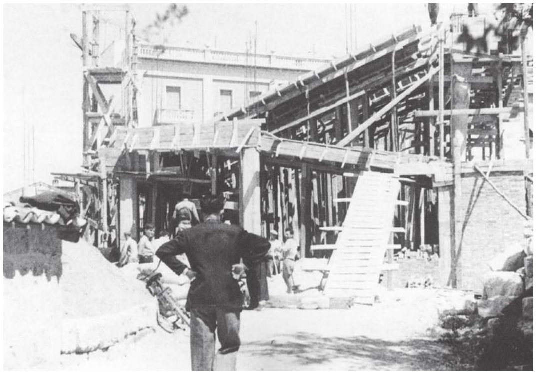
Two ramps lead from the opposite sides of the spacious lobby, aligned along the large windows (that open the internal space to the exterior through a suspended garden), connecting the balcony at the end points of a corridor which divides its upper and lower areas. The balcony is built as a cantilevered structure over the stalls.

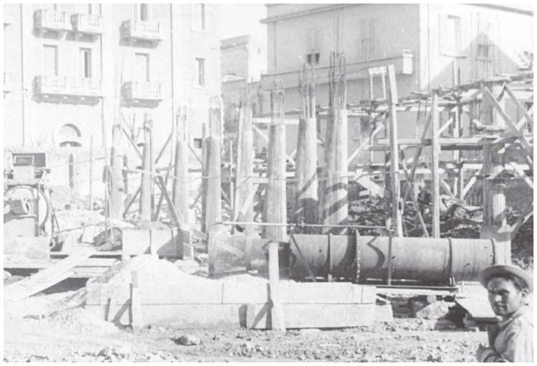
[22] See Levi C., *"Cristo si è fermato a Eboli",* Edizioni Einaudi, 1990

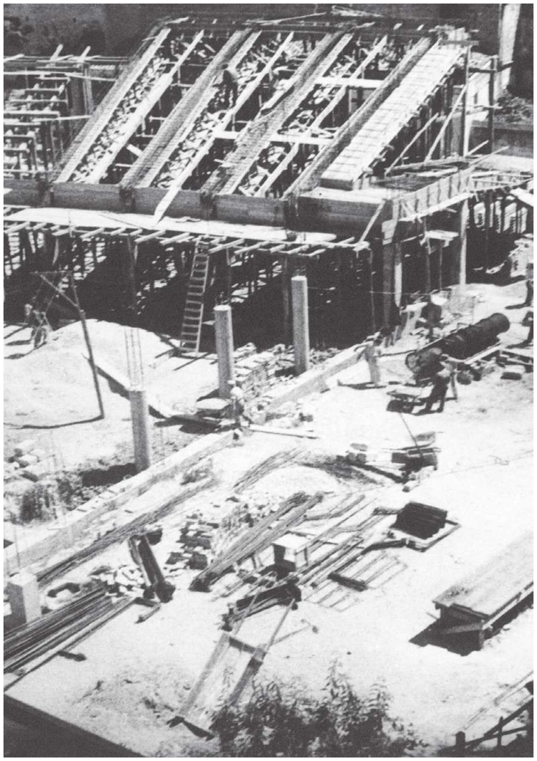
[23] Between 1992 and 1995, a series of projects and trials were prepared to bring facilities in line with the new safety standards for public venues. For safety reasons, it was envisaged to reduce the number of seats: in the stalls from 520 to 489 and in the gallery from 529 to 499.

[24] It was completely replaced in 1978. However, the upper part of the façade was modified and completed in 1995 according to the proposal by Mr Gregorio Padula, the owner of the building.

Plate 5.5: Historical images of the construction site (1947)







The load-bearing structure (Plate 5.5)[25] was entirely built of reinforced concrete; Stella used the structural components to formally express the space either by placing the tall, round columns in full view in the theatre hall, standing free along the perimeter walls, or by emphasising the brave curvilinear cantilever of the balcony, or by the specially shaped columns of the foyer ramps (with a cross-section which is gradually reduced from the floor to the mid-height and then expanded towards the top of the column) (Plate 5.6).[26]

The roof structure spans the entire space with a large vault consisting of arched reinforced concrete beams.

Together with these spatial and architectural components, there are technological aspects related to the acoustics such as the reflection and the absorption characteristics of the lateral walls which eliminate distortion and concentration of sound, and the finishes whose formal and material design confers organic unity and a "strong" image to a deliberately "modern" work.[27]

The nature of the ground clay led the structural

[25] Picture from the private archive of the architect Luigi Acito, Matera.

[26] Picture from the private archive of Dr Angela Montemurro, Matera (foto VASARI, 1949, Roma).

[27] Acito L., "Un'invenzione periferica", Casabella, n. 730, February 2005.

Plate 5.6: Inside structures (detailed of the ramp and of the hall)

engineer (Eng. Mario Vigliar)[28] to opt for inverted reinforced concrete beams. The concrete was normally prepared on site by measuring out in a concrete mixer the cement originating from Bari, the sand from Bradano and the gravel from the local quarries. The structural skeleton consists of reinforced concrete columns and beams, gradually built as the walls were rising. The columns´ sections assumed various forms that ranged from a square, for the columns embedded in the outer walls, to a circle in the stalls or with a gradually varied form in the foyer. All the columns are visible to confer more flexibility to the internal space. The attic structure is a mixture of different reinforced concrete beams finished off with a plaster layer on the internal vault surfaces, while the finish of the external vault surfaces varies in relation to the different uses of the internal spaces.

With regard to vertical connections, the Duni Theatre is served by different staircases and secondary vertical connections. In the entrance hall two opposite ramps link the foyer to the overhanging balcony. The structure of the balcony (Plate 5.7)[29] is of reinforced concrete with a 12% gradient. The ramps are covered in green linoleum, and the glass parapets have maple handrails.

[28] Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare"*, Edizioni Librìa, Melfi, 1999, p. 63.
[29] Image from the private archive of Dr Angela Montemurro - Matera (foto VASARI, 1949, Roma).

Plate 5.7: Image of the stalls and the balcony

Other two staircases link the lower and the upper gallery with the entrance from Lucana Street, while another reinforced concrete emergency staircase connects the upper gallery and the projection room to the entrance from Roma Street. Other metal staircases provide vertical links between different service rooms in the building and on the stage.[30]

5.2.2 On site tests: formulation

As mentioned in the previous case study, a correct formulation of the investigation campaign guarantees a higher "reliability" of the obtained results; the selection and the location of the test points are, therefore, fundamental. Still, this selection is not always easily made, especially when the "structural surfaces"[31] of the investigated elements are not visible as in the case of Duni Theatre where they are covered with another material or integrated within other fixed (external walls or partitions, etc.) and/or mobile components (furnishings).

In the case of Duni Theatre, the columns have a finishing layer realised with the "fired stucco" technique that was widely used in construction works in the first half of the 20th century, generally consisting of a mixture of Greek tar, yellow wax, turpentine and marble dust.[32] Obviously, each local worker had brought his own variant of the composition and the application of stucco. Vito De Natale, the stucco worker on the columns of the Duni Theatre, in addition to the layers of lime plaster with white cement, slaked lime, marble and tufa dust, has made a "polishing" mixture using slaked lime, soap flakes, pitch, egg yolk and earth colours. The polishing entails the treatment of the surface with a hot iron until it shines, and then further rubbing with a cotton cloth after the drying process.[33]

This characteristic was an essential element that has strongly conditioned the execution of the tests both (1) because of the influence which this layer might have on the result of the analysis, and (2) because of the difficulty to undertake the tests (particularly the sclerometric test) without also causing a damage, although minimal, to the aesthetics of the above polishing. All the interior columns that are not inserted in the external walls and/or integrated with fixed or mobile furnishings were tested (Plate 5.8).[34]

[30] Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare",* Edizioni Librìa, Melfi, 1999, pp. 34-48.
[31] The term "structural surfaces" defines here the structural component surfaces without any finishes, i.e. with visible structural areas.
[32] The description of the composition of different layers has been provided by L. Scolari, *Le opere in stucco,* in M. Bertoldi et al., 1983, pp. 97-98.
[33] Acito L., *"Il Cinema-Teatro Duni di Matera. Un'architettura moderna da tutelare",* Edizioni Librìa, Melfi,1999, note 20, p. 68.
[34] Image from the private archive of Dr Angela Montemurro – Matera (foto VASARI, 1949, Roma).

The selection of the internal structural components was also related to the process of "natural aging" of reinforced concrete (they are not subjected to the external aggressive agents that might catalyse the aging process of the material in a "pathological" way and compromise the "reliability" of the diagnostic tests).
As in the case study in Glasgow, the selection of the location of investigation points was completely random (also to guarantee the "representativeness" of the investigation for the entire structure[35]) with the reference to the identification of "homogenous" areas[36] and to the surfaces without degradation. The methodology used to undertake the tests was – as mentioned – the direct survey of data *in situ*. More precisely, concerning the sclerometric tests, they were always executed by placing the instrument orthogonally on the investigated surfaces. The ultrasonic tests were undertaken by using the direct investigation method (see Chapter III).

5.2.3 On site tests: analysis and results

The tests were undertaken in March 2011 (external environmental conditions: temperature between 6-12°C and air humidity 45-69%). In this case also, the number[37] of ten values per each test was adopted; their average value was

Plate 5.8: Details of structure of the gallery (a) and of the stalls (b)

considered as a typical example. Following the calibration of the instruments[38] (by using an anvil for the sclerometer and a sample test for ultrasound tests – see Chapter III), in the same way as in the case of the Lion Chambers, three different investigation points were selected for each component (Plate 5.9): at 0.50 m (Table D), at 1.00 m (Table E) and at 1.50 m (Table F) from the floor. This selection differs from the one for the Lion Chambers and was motivated, above all, by logistics and opportunity; in fact, the height of the columns[39] is such that the help of tools and particular devices was needed to access – safely – the middle part or the top of the structural component.

[35] Masi A., *"La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non distruttive"*. Il Giornale delle Prove non Distruttive Monitoraggio Diagonstica, n. 1, 2005, pp. 2-3.
[36] The "homogenous" areas are defined here as the surfaces that show the same technical, material and structural characteristics; therefore, they can be considered "qualitatively" representative of all the components that show the same characteristics.
[37] The number of required tests to guarantee the reliability of the results is determined by the Italian standard - OPCM 3274/2005, Ordinanza del Presidente del Consiglio dei Ministri of 20 March 2003 "Principal elements regarding the general criteria for seismic classification of the national territory and of the technical standards for construction in seismic areas", revised by Gruppo di Lavoro istituito dal Dipartimento di Protezione Civile
[38] The sclerometric test is determined by the standard EC 1-2010 UNI EN 12504-2:2001, while the ultrasound one is set by the standard EC 1-2010 UNI EN 12504-2:2001.
[39] The average height of the columns is around 12 meters from the floor level in the stalls and on the ramps (the columns become thinner towards the middle part and wider towards the top); the columns on the gallery are around 3 meters high (they are thinner towards the top).

Table D: Elevation from the floor [50 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pc_1	37,6	3430,65	**19**
Pc_2	37,25	3421,15	**19**
Pc_3	36,25	3426,6	**18**
Pc_4	36,95	3422	**18**
Pc_5	39,55	3439,6	**21**
Pc_6	38,3	3464,3	**20**
Pc_7	36,6	3445,6	**19**
Pc_8	39,25	3449,6	**21**
Pc_9	36,75	3423,3	**19**
Pc_10	37,5	3427,85	**19**
Pc_11	38,9	3433,35	**20**
Pc_12	37,9	3447,75	**20**
Pe_13	38,6	3144,4	**16**
Pe_14	36,5	3128,5	**15**
Pe_15	37,2	3149,8	**15**
Pe_16	38,2	3171,9	**16**
Pe_17	36,9	3160,9	**15**
Pe_18	37,5	3118,0	**15**
Pe_19	36,95	3139,0	**15**
Pe_20	37,45	3161,2	**16**
Pe_21	38,4	3166,0	**16**
Pe_22	36,9	3159,2	**15**
Pe_23	37,9	3170,1	**16**
Pe_24	39	3155,1	**16**
Pe_25	37,35	3163,9	**16**
Pe_26	37,45	3133,0	**15**
Pe_27	38	3128,3	**15**
Pe_28	37,55	3142,7	**15**

Table E: Elevation from the floor [100 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pc_1	37,75	3422,7	**19**
Pc_2	36,35	3428,75	**18**
Pc_3	36,95	3418,3	**19**
Pc_4	38,35	3427,65	**20**
Pc_5	39,4	3431,7	**20**
Pc_6	39,05	3430,1	**20**
Pc_7	36,35	3427,75	**18**
Pc_8	38,05	3433,5	**19**
Pc_9	37,2	3434,05	**19**
Pc_10	37,8	3432,7	**19**
Pc_11	38,8	3424,1	**20**
Pc_12	39,35	3439,05	**20**
Pe_13	39,05	3172,5	**17**
Pe_14	36	3158,5	**15**
Pe_15	38,7	3170,4	**16**
Pe_16	37,65	3163,3	**16**
Pe_17	38,15	3152,6	**16**
Pe_18	38,4	3162,1	**16**
Pe_19	37,55	3163,7	**16**
Pe_20	36,3	3158,8	**15**
Pe_21	38,4	3166,9	**16**
Pe_22	39,75	3171,5	**17**
Pe_23	38,45	3152,4	**16**
Pe_24	39,05	3188,6	**16**
Pe_25	38,35	3158,1	**16**
Pe_26	36,8	3187,8	**15**
Pe_27	37,8	3180,9	**16**
Pe_28	37,9	3187,7	**16**

Table F: Elevation from the floor [150 cm]

Structural element	Average rebound value	Average ultrasonic speed [m/s]	Rc concrete SonReb Method [MPa]
Pc_1	37,5	3430,5	**19**
Pc_2	35,55	3440,5	**18**
Pc_3	38	3437,5	**20**
Pc_4	37,3	3454,45	**19**
Pc_5	37,65	3405,9	**19**
Pc_6	37,4	3480,85	**20**
Pc_7	38,15	3447,75	**20**
Pc_8	35,85	3476,5	**19**
Pc_9	38	3455,85	**20**
Pc_10	38,8	3433,9	**20**
Pc_11	38,2	3436,1	**20**
Pc_12	38,7	3450,35	**20**
Pe_13	38,6	3155,2	**16**
Pe_14	36,9	3167,5	**15**
Pe_15	38,2	3166,1	**16**
Pe_16	38	3171,8	**16**
Pe_17	37,55	3159,5	**15**
Pe_18	38,05	3133,5	**15**
Pe_19	37,55	3172,6	**15**
Pe_20	38,25	3159,3	**16**
Pe_21	37,85	3166,4	**16**
Pe_22	36,9	3185,4	**15**
Pe_23	38	3159,9	**16**
Pe_24	35,85	3183,6	**15**
Pe_25	38,1	3166,2	**16**
Pe_26	37,4	3155,0	**15**
Pe_27	36,95	3165,6	**15**
Pe_28	39,05	3168,2	**16**

Therefore, the selection was made according to the easiness of the execution of the tests and – in analogy with the above Scottish case study – by investigating the columns at the points of major stress (close to the base) and having assumed (1) an uniformity of the loads and the imposed loads distribution (due to regularity and modularity of the structure) and (2) a homogenous condition of load (also due to the absence of any cracks that would induce different thinking).

The obtained results – as the tables show – highlight the homogenous results in relation to the type of the component geometry. The round columns have returned values of the sclerometric bounce index (average value of the ten measurements for each point) between 35.55 and 39.35 uniformly distributed on the surface (i.e. independently of the number of the investigation tests). The ultrasound tests have returned average values of the ultrasound speed between a minimum value of 3405.90 m/s² and a maximum value of 3480.85 m/s². Comparing the results by using the SonReb method (see Chapter III), the values of the resistance of concrete were obtained from a minimum value of 18 MPa to a maximum value of 21 MPa. The columns with the elliptical profile (and with a smaller section at mid-height) have returned the sclerometric bounce index (average value of the ten measurements taken for each point) between 36 and 39.75 uniformly distributed on the surfaces (i.e. independently of the number of the investigation tests). The ultrasound tests have returned average values of the ultrasound speed between a minimum value of 3118.00 m/s² and a maximum value of 3188.60 m/s2. Comparing the results by using the SonReb method (see Chapter III), the obtained values of the resistance of the reinforced concrete are between a minimum value of 15 MPa and a maximum value of 17 MPa.

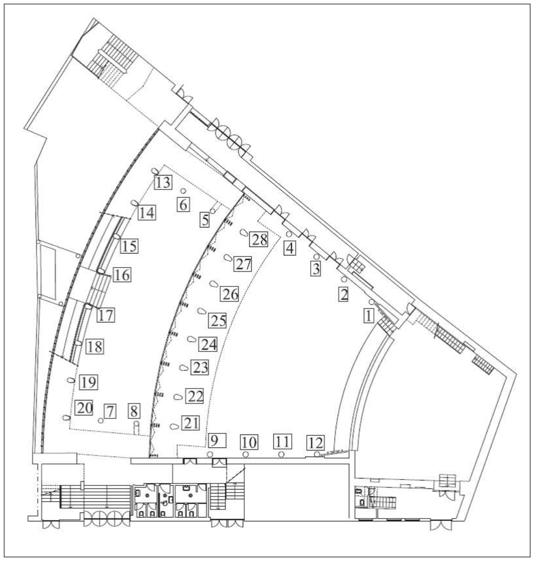


Plate 5.9: Selection of the columns for testing

A chain of events, together with causes and impacts, over the course of the 19th century initiated a radical transformation in lifestyle all over Europe and the USA. The process permeated all aspects of life, from those of a more specifically socio-organisational nature, to those of a more scientific nature, in all its meanings: economic, cultural, traditional and industrial, including all the phases of the architectural process, both public and private. Specifically, materials evolved as did functional needs, thus changing building technologies and techniques, as well as the structural choices made for the buildings, even regarding the professionals involved and consequently the technical standards used.
Construction proceeded slowly according to a "rule of art" and a consolidated knowledge, strongly linked to the materials and local expertise. At first, the knowledge was transferred verbally and practically, from one generation to the next, and then through the drafting of practical manuals. A more de-contextualised building procedure followed due to a convergence of industrial materials and preconstructed models, patented and subjected to serialization and standardization, whose circulation and innovation requested a radical revision of the construction procedure and the standards being applied to it.
This revision of the construction procedure (at the end of the 19th century) entailed investigating and describing the type and quality of the new materials (mortar, cement, concrete, pozzolana-based cement and reinforced concrete). Later, the structure was studied, proposing calculation models that evolved in Italy in light of local experimental and theoretical experiences. In fact, the novelty at that time was even the scientific approach itself (regarding structural, technical and technological problems), which can be defined as "preventive experimental". In the face of a new innovative material – cement in all its forms – both in Europe and America, the path followed to gain knowledge and the investment made in the material itself, single elements or entire buildings, is the consequent determination of proven facts which verify quality and characteristics of the material.
This is how the first real practical manual of the Monier patent appeared, the "Monier-Brochure"(1887), which was nothing more than the systematic organisation and recording of the results of the load tests and fire resistance tests, the adhesion between iron and cement, and the durability of iron in the cement which Wayss & Freytag had conducted on the prototypes created in Cologne, Berlin and Breslau. In 1904, the first technical bulletin "Tests of Reinforced Concrete Beams" was published by Robert Talbot from the University of Illinois at Urbana-Champagne. This was the result of the tests run on concrete in its civil engineering laboratories. The first French standards for reinforced concrete were published in 1906. This was the product of the experimental trials carried out over the course of three years under

the guidance of the Government Commission of Public Works, established in 1901 (Plate C).
The restoration and reuse of built heritage enable its reintegration into the active part of the fabric of towns and cities by recognizing and protecting the historic and architectural values "written" on their walls, in the spaces and by the forms. The objective of the restoration and reuse is not only to preserve built heritage, but also to confirm a hypothesis regarding its adequate use and value.
The restoration and reuse thought of in this way, apart from guaranteeing the success of the intervention, or in other words, the rebirth of the building, would also respect the idea of pre-existence, in which the traces of past services and the capacity to give historic testimony are valued.

Lion Chambers (Glasgow, UK)
The Lion Chambers (1904-07) was the first non-industrial reinforced concrete building in the world built before 1910 that did not disguise the nature of the building material whose application in architecture was a new challenge to architects from around 1900. It contributed to the development of innovative design approaches for the use of reinforced concrete in architecture. Thus, it is a unique building among all 'A' listed buildings in Scotland and in the world. As many other brave experiments, it did not immediately get everything right – there was no thermal insulation to external walls, the roof and the foundation slab. The lack of thermal insulation and poor or no damp protection have caused partial deterioration of concrete surfaces and some reinforcement bars. This is not a non-surmountable technical challenge for restoration, conservation and reuse of the building, as shown in the research

Plate C: Experimental trials carried out on beams in reinforced concrete.

report recommendations in 2001. The challenge to everyone concerned with the preservation of this rare building is to propose a new use and a related business setup that would enable bidding for funding from a range of funding sources available for preservation and reuse of the built heritage. This could include not only national, but also European funding for sustainable reuse of built heritage.
The 2001 report provided a feasible option for the interventions required to repair the Lion Chambers to the level that would enable its use for domestic or similar occupation while preserving its architectural authenticity. It did not suggest a wider range of recommendations for more sustainable repair of building fabric or consider the feasibility of installing sustainable building services such as local generation of energy for heating, hot water, cooling and ventilation. Along with the earlier recommendations, the above research proposes a consideration of new, high-performance thermal insulation materials and technologies for increasing the energy efficiency of the building and improving its sustainability.
As the 2001 report indicated that the works required to strengthen the structure for office

use would be extensive and, therefore, a more expensive option than residential or similar use. The previous office use is unlikely to continue as the seven co-owners of the property could not afford to pay maintenance costs which were much lower than the investment required for strengthening the structure. In that context, the owners should be made aware of the options for the building's future use and invited to engage in a dialogue with Historic Scotland on a way forward that would ensure the preservation of the Lion Chambers and the reuse that would generate income for building maintenance in the future. A non-profit organisation might be a suitable model for a business setup that would be eligible for applying for funding to a range of funding bodies that support the sustainable restoration of built heritage.

Duni Theatre (Matera, Italia)

The experimental research project on the consistency of structural materials, aimed at the restoration and improvement of the Egidio Romualdo Duni Cine-Theatre in Matera (1946-49), came out of a course of study and research which looks at the architect and his projects and what they have represented for the town.

Ettore Stella was ahead of his times regarding modern architecture, which made the town of Matera a laboratory for testing theories and models circulating throughout the Italian architecture during the 1950's and 60's. Ettore Stella, intellectual and architect, brought a new language to Matera, which he had learned from debates going on in the Roman school of thought at that time. This new language sought to reunite the architectural aspirations with technological inventions and a civic spirit, immediately after the war.

Thus, Stella´s architecture was entwined with civic aims. From this point of view, the building use responded well to the principals for which it was an example.

The hypothesis of restoration, respecting what already exists, recovering the signs of the past and that which it represents, is formulated so as to guarantee a new, long life for the building.

The building remains absolutely recognizable to everyone's eyes and continues to represent that which could be defined as the best modern architecture in Matera.

Test analysis results

The investigations carried out show equal values of the rebound index. Comparing the obtained results with the table provided by the manufacturer of the sclerometer (see Plate 3.2 – Chapter III), one obtains resistance values for the concrete which are superior to those obtained using the RILEM NDT 4 table (see Table 3.11 – Chapter III).

Such apparent differences are explained by the influence of ultrasound speed (which qualitatively defines the consistency of the concrete inside the structure).

The sclerometer index only gives information regarding the surface layer of the building's structure. In fact, due to the effects of the natural ageing, catalysed by the presence of humidity, surface layers of concrete are affected over time by carbonatation, which increases surface rigidity, providing as a result a greatly "altered" rebound index (much greater than one would have under normal conditions).

On the other hand, the ultrasound speed, on the contrary to resistance, is inversely proportional to the age of the concrete (this seems to be due to the cracks that occur and reduce the speed). The hardening process continues over

time with a consequent increase in resistance, which diminishes with the passage of time[1].
While the humidity content increases, an increase in speed of up to 5%[2] is registered, with a decrease in tensile strength. However, it is not influenced by the level of stress in which the tested element is found, until the stress on the material is equal to about 50% of the tensile strength. For higher stress levels, a reduction in speed is observed, caused by the formation of cracks[3].

Lion Chambers

The tests run on the structure of the Lion Chambers have shown:

- a substantial homogeneity of values obtained for each level investigated;
- the sclerometric tests show an average rebound index value of between 37.35 and 47.38. Compression resistance values for cubes of concrete have been reported in the table provided by the equipment manufacturer (see Figure 3.2 – Chapter III) and in numerous studies found in the literature, giving values between 350 kg/cm² and 460 kg/cm²;
- the ultrasound tests show average ultrasound speed values to be between a minimum of 2,920.8 m/s² and a maximum of 3,191.65 m/s². Comparing the results obtained from ultrasound tests with the studies provided by the technical literature, the values refer to concrete which has been placed under conditions that vary between bad and acceptable, and so, are inferior to the average speed of 3,000 m/s, which many studies (see Table 3.5.-3.6-3.7 of Chapter III) from the literature note as the minimum acceptable threshold. Nevertheless, it should be noted that the "anomalous" values – in all probability – are to be attributed above all, to the non-homogeneity of the surface finishing layer, which prevents the proper passage of waves within the structure;
- comparing the results using the SonReb method (see Chapter III), characteristic resistance values for concrete are obtained which go from a minimum of 14 Mpa to a maximum of 22 Mpa. These give compression resistance values for concrete of between 140 kg/cm² and 220 kg/cm², lower (less than half) of what would have been obtained using each test singularly.

Duni Theatre

The tests run on the structure of the Duni cine-theatre have shown:

- a substantial homogeneity for the values obtained for each level investigated in function of the type of geometry of the element itself (the round columns of the stalls and/or the elliptical shapes (and tapered) for the ramps in the lobby and for the structure of the balcony);
- for the first type (round columns), the sclerometric tests showed an average rebound index value to be between 35.55 and 39.35. Compression resistance values for cubes of concrete have been reported in the table provided by the equipment manufacturer (see Plate 3.2 – Chapter III) and in numerous studies found in the li-

[1] Masi A., *La stima della resistenza del calcestruzzo in situ mediante prove distruttive e non istruttive.* Il Giornale delle Prove non Distruttive Monitoraggio Diagonstica, n. 1, 2005, p.6.
[2] American Society for Testing and Materials (ASTM), 2002. Standard Test Method for Pulse Velocity Through Concrete, ASTM C 597 – 02.
[3] Braga F., Dolce M., Masi A., Nigro D., *Valutazione delle caratteristiche meccaniche dei calcestruzzi di bassa resistenza mediante prove non distruttive,* L'Industria Italiana del Cemento n. 3, 1992.

terature, giving values between 300 kg/cm² and 390 kg/cm². For the elliptical type of column (tapered), the average rebound index value is between 36 and 39.75. Compression resistance values for cubes of concrete have been reported in the table provided by the equipment manufacturer (see Plate 3.2 – Chapter III) and in numerous studies found in the literature, giving values between 310 kg/cm² e 390 kg/cm²;

- for the first type (round columns) the ultrasound tests show average ultrasound speed values to be between a minimum of 3,405.90 m/s² and a maximum of 3,480.85 m/s². Comparing the results obtained from ultrasound tests with the studies provided by the technical literature, the values refer to concrete which has been placed under conditions that have been defined as acceptable, (see Table 3.5.-3.6-3.7 of Chapter III);
- for the elliptical type column (tapered) the ultrasonic tests show average ultrasound speed values to be between a minimum of 3,118.00 m/s² and a maximum of 3,188.60 m/s². Comparing the results obtained from ultrasonic tests with the studies provided by the technical literature, the values refer to concrete which has been placed under conditions that have been defined as acceptable, (see Table 3.5.-3.6-3.7 of Chapter III). The evident non-homogeneity of the results obtained for each of the two types of columns investigated can – in all probability – be attributed, above all, to the non-homogeneity of the surface finishing layer, which prevents the proper passage of waves within the structure;
- Comparing the results using the SonReb method for the first type, (round columns), (see Chapter III), characteristic resistance values for concrete are obtained which go from a minimum of 18 Mpa to a maximum of 21 Mpa. These give compression resistance values for concrete of between 180 kg/cm² and 210 kg/cm², lower (almost half) of what would have been obtained using each test singularly. For the elliptical type of column (tapered), characteristic resistance values for concrete are obtained which go from a minimum of 15 Mpa to a maximum of 17 Mpa. These give compression resistance values for concrete of between 150 kg/cm² and 170 kg/cm², lower (almost half) of what would have been obtained using each test singularly.

The tests carried out are the basis of a diagnostic project that is possible to implement and monitor to guarantee a deeper knowledge, with the goal of attaining a level of thorough understanding aimed at the "preservation and improvement" of *"Modern Architecture"* in Europe.

"The modern building must derive its own architectural significance exclusively from the power and coherence of its organic proportions: it must possess its own declared truth, a logical transparency and be immune to lies and triviality."

Walter Gropius, 1935

"Restoration. The word and the thing are modern."

Eugene Viollet-le-Duc

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