Buildings of beginning of ‘900 between tradition and innovation: From the art of building in the treatises to building practices of handbooks

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Research faces the study of evolution process affecting building of first decades of XX century; such building where characterised by transition from old and reliable construction techniques —the art of building, codified in theoretical treatises between humanistic and scientific knowledge— to new and experimental, for that age, materials and building systems —explained in friendly handbooks aimed to divulgence of technical innovations and to practice education of professionals, master builders and students.

The age is marked by a wide interest toward new materials and new construction techniques culture for which there is a sure trust in their usability and durability in the time. For these reasons, a gradual and continuous process of contemporary use and/or substitution of traditional construction materials and techniques with modern ones took place (from use of simple and cast iron to more flexible concrete, iron reinforced or not); such process progressively involved even common buildings such as residential ones when such materials and techniques went into market marked by features of higher economy in terms of time and costs.

In particular, the research highlights material-technical-technological evolution path generated by gradual introduction of new materials and substitution of single elements of building first —flat arches, arches and ceilings with iron and/or concrete/tile structures—, then of whole parts —stairs, vertical backbone and transversal frames with beams and pillars in reinforced concrete— and finally of whole bearing masonry box.

In this way it is possible to define, as much to a level of building complex in its whole as to a level of single elements and/or subsystems, material, technical, technological features of the «new» building type which has long been neglected and today in the focus of interests and studies, for historical and architectural aspects, but still not much analysed under technological and structural profile.

PREFACE

Buildings between the end of XIX and beginning of XX century are characterised by transition from traditional materials and old and well-established construction techniques to new materials and to modern techniques and technologies. There is the presence of traditional and modern culture which, within the enthusiasm of reached and reachable results look with sure and absolute trust at innovative techniques and materials, at their usability, at their durability in time.

All of this let operator require a multidisciplinary knowledge and continuous updating which is supported by spreading of a technical press made of manuals and friendly handbooks of popular and practical features.

This study faces evolitional process which affects construction, from gradual introduction of new
materials and substitution of single elements of buildings—flat arches, arches and ceilings of iron and/or brick-concrete structure—up to construction of new building with reinforced concrete structure.

Through reading and analysing of technical information related to construction elements contained in manuals, it is intended to analyse historical, technical, typological evolution of buildings, taking into account specific constructive aspects and defining material-technological-structural features.

The aim is systemising of knowledge as a preparatory stage to analyses of specific decay processes of such building heritage and to definition of methodologies aimed to their conservation.

With present work-in-progress a first path is traced in order to define modality and operative processes limited to singular cases but extendible, in the methodology, to whole building complex.

CONSTRUCTION TRADITION IN TREATISES

Up to XVIII century, building is founded both on a consolidated technical knowledge transmitted from generation to generation and on generics theoretical aspects of Architecture expressed within Treatises.

Traditional building practice, technical procedure of an architecture intended as mechanical art, is then originated and transmitted by architects and workers: local construction traditions, quality of materials of the territory and skill of workers condition and have influence on characters.

Treatises mainly concentrate on theorisations of general and cultural kind, both for strictly didactical aspects of transmission of technical knowledge and for larger concepts of encyclopaedically characters. In such view the attention, from Alberti to Palladio, from Vignola to Serlio, is mainly located upon basic «rules» for designing and architectural composition of building, rather than upon technical prescriptions for building it. Even when the intention is clearly practical and popular, as in case of Rusconi Treatise, construction practice is described and illustrated in an ideal vision of building reality and human work founded upon philosophical principles.

Respect of fundamental values of symmetry, order, precision in execution and quality of materials allows producing the beauty and the harmony: practical realisation is instead committed to respect of codes and consolidated habits which constitutes that large technical-cultural heritage which is named as «Best Practice Codes». Such Codes, within unitary conception of theory and practice which is proper of humanistic culture, are considered the fundament of ideological premises of Architecture and they are the shared patrimony of all operators of building process.

With Age of Enlightenment and French Rationalism, a scientific approach to building begins to establish, with attention to single building operations which lead to realisation of building.

Treatises start to lose part of their strong theoretical connotation and the interest to the object in its whole, thus giving more consideration to practices and construction modalities: the aim of treatises turns into «let known arts improve and let ancient lost arts be retrieved» (Diderot and D'Alembert 1772), while spreading of rationalist thesis implies establishing of «mathematical and physical principles applied to different art operations» (Rondelet 1802).

Treatises are then affected by an evolution originated from confront between the Art of Building, the Construction as a Science and the Academic Beauty, thus trying to find an unifying element in the recourse to scientific and mathematical method. All of this progressively changes contents: if building is a science then description of techniques and construction details is necessary.

A clear example is given by Rondelet Treatise itself; in it, the interest in the scientific problem of definition of criteria for determination of building stability, for comprehension of mechanical behaviour of structures and for optimal determination of geometrical dimensions of architectural and structural elements, is showed with scientific strictness through illustration of historical experiences and recent exemplar cases, but also through consolidated practises.

BUILDING TRANSFORMATION BETWEEN XIX AND XX CENTURY

Starting from Industrial revolution, Technical-Scientific turmoil involves all knowledge sectors without distinctions, even included consolidated construction practise, thus provoking a more and more rapid and capillary spreading of produced materials, together with knowledge and experience done.
In Construction field, the unavoidable transferring of knowledge between different sectors of production determines the passage from a «craft kind of knowledge» to an «industrial type» following a process which leads to separation between ideation moment of design and is realisation moment.

Transformations, which Industrial Revolution has provoked upon construction process, are well known. Without recalling them, it has to be highlighted that such mutations thrown into confusion construction tradition under three fundamental aspects.

As first, materials and construction methods change: new materials such as cast iron, iron, glass, new kind of bricks, and, moreover, cements and reinforced concrete are produced; traditional materials are craft in a more rational way and distributed more easily and cheaply; scientific progress allow to measure materials resistance and to put them in work in a cheaper way; site equipments improve and construction machine use is spread; developments of descriptive geometry allow to represent in an univocal way all aspects of construction. This, for example, determines gradual substitution of wooden beams with iron ones, in a first stage as main bearing structures and then as secondary together with spreading of use of brick elements (mechanical bored bricks). Or again, the substitution of internal bearing masonries with cast iron columns took place in order to obtain less bulk and more flexibility.

As second, new building types appear, in order to satisfy needs of Industrial Society —plants, warehouses, depots, markets and slaughterhouses, train stations, rails, and even cheap houses— and quantities increase due to rising need of infrastructures for the territory.

As third, a new sense of time is developed, in which buildings are something which is not to be considered unchangeable and «definitive», but only the answer to a contingent need.

All of this also changes common construction, when rapidly increases introduction of «new» materials within usual building procedures, thus provoking remarkable mutations in Architecture, as a global fact and equilibrated result of different components. Practically, under pressure of industrial progress a difference increased between traditional construction theory and new building practice, which means between Architect figure which was linked to theorisation of Beauty (and then progressively strained to decorator role) and Engineer figure which was synonymous of progress and concreteness (and apparently more ready to satisfy contractor’s and production world). Roles and competence of building process operators turn and even scholastic system transformed itself: progressively, the specificity of Architects and Engineers characterises itself in a not uniform manner, intermediate classes were born of experts and master builders with responsibility of site and execution of buildings, applicative schools of engineering were born.

Such evolutional process which affects construction determines spreading and expanding of technical press: near treatises and their new editions, magazines start to appear and strictly educative books are supported by operative and popular handbooks.

Several are the reasons at the base of different publications: firstly, the need for documenting conditions of economical development and for receiving technical and social problems of nineteenth-century town; as second, industrialisation which requires more and more a scientific and technical culture (which put itself on a culture now seen as abstract, which had been mainly humanistic and seen at the base of knowledge) conformable to indications of new positivism.

Further reason is the need for an updated and deep knowledge of new materials and technologies, both for their production and their placing on site: fast progresses of those years in all sectors request to different actors of construction process, in short time, a multidisciplinary knowledge and technical competence and capacity of a continuous updating. An example of this, it is the publication, in 1888, of first volume of «Dictionary of Civil, Mechanical, Military and Naval engineering» from Brine and Spon; the book contained all new terms of technical nomenclature and it represented the update of «Encyclopédie» from Diderot and D’Alembert. Another case is represented by Curioni’s Manual (Curioni 1868), which was published in six volumes from 1865 to 1870 when in 1873 already saw an appendix for its update; the updating opera went on up to 1893 when sixth appendix was published after his death.

At last, the already said transformation of roles and competences of operators of building process determines spreading of a press whose character was
extremely popular, with schemes, handbooks and illustrations as more documentary was possible. As an example, in Italy, numerous manuals from Hoepli, Vallardi, UTET published in those years, were the answer to a spread need for education of a new managing and intermediate class that had in common their technical education.

That is why manuals collect available documentation in construction field, with the aim to provide young graduated and professional with a large knowledge of practical notions, in a way to let them be expert from building practice after they had studied their theories. Generally, most faced themes are the ones related to material and production evolution, to construction methods most commonly approved or most common in practice, to codified practices and to innovations on which the consent was going to be produced, to birth and evolution of residential problem, to the whole of code and legislative tools, to building types and related hygienically-sanitary problems.

BUILDING BETWEEN TRADITION AND INNOVATION

Study of technical press allow to trace in a precise way the historical evolution of building in the mentioned period, characterised by gradual but continuous supporting process and/or substitution of materials and traditional construction techniques with modern ones. In other words, manuals define the state of the art in construction: detailed description of executive construction techniques, of operations and site equipments, of available materials, allow the reconstruction of building process organisation, of construction processes and of realisation modality. In particular, the analyses of technical information related to construction elements contained in manual literature of 1850–1940 period allows precise definition of material, typological, constructive, technological and structural characters of building in first decades of XX century, as much at a general level as at a building complex, single sub-systems and construction elements level.

Contemporaneous and parallel existence of traditional aspects together with innovative ones determines buildings based upon general theorisation from one side and upon practice and direct on-site testing from the other. Building practice lies, however, on a scientific approach in which operator knows theoretical aspects of materials and innovative techniques, experiences done and obtained results, indication and practical notions for their use. Such approach is already present within the articulation of exposition of subjects from Curioni’s Manual (Curioni 1868).

Technical knowledge is often limited to a minimum level which allows the comprehension of new solutions and proposed technologies. An example is realised by chapters on civil plants from Donghi’s Architect Manual (Donghi 1905), in which practical and popular aim imposes, even in a large text, to dedicate only short notions on scientific and technical principles at their base.

Fast spreading process of new materials and techniques determines an increase of the complexity level in building, with a progressive dismissal of traditional universal and whole vision of the building: building complex starts to be resolved in its main components of which different typological and technical possible solutions are studied together with sequence of construction phases and putting on site of materials and construction elements. This is easily findable in the sequence of graphical schemes within Copperi-Musso’s Manual (Copperi and Musso 1870) which give exemplifications in a simple and intuitive way, even with recourse to axonometric views and sections in order to ease comprehension of construction techniques, a complex building technique, from the big scale to details of windows and door hardware.

A building technique, articulated in general components take place; each element is untied from particular applications and/or local uses in order to let the operator use them in most opportune ways that means according to needs deriving from particular exigency. Such fundamental concept pervades Breymann’s Manual (Breymann 1895), where, as an example, in parallel, notions for structural calculations with new materials (even with complex formulas) are described as much as schemes for pre-dimensioning of elements (i.e. iron beams or slabs), thus anticipating what is a feature of contemporary technical documentation.

This is then the evolution toward buildings realised by assembling of technical solutions pre-constituted or ideals, optimisation of shape/type —construction/material relation, to adequate or not to particular
context. In this view Manuals become sort of referring «Catalogues» for construction operators. An example is Formenti’s Manual (Formenti 1893), in which meticulousness of representation and technical particulars showed in numerous graphical schemes seem to testimony solidity and quality of construction systems, moreover of new patents or mixed systems with new materials.

Buildings of first decades of XX century, then, intermediate between pre-modern masonry construction and «modern» reinforced concrete ones, seem to be characterised by complex and articulated construction systems in which there is a co-presence of elements and materials referable to traditional building coded in «Best Practice» — vertical bearing structures made of stone masonries and/or bricks and ceilings made of stone vaults and/or bricks and/or wooden slabs — and of materials and elements from Industrial Revolution — new materials such as iron and concrete, ceilings made of wood and iron, of iron and bricks, of reinforced concrete, and vertical elements made of cast iron columns, beams and pillars in reinforced concrete.

In this paper it is considered to be important to underline two exemplificative aspects of evolitional path of buildings in those years: on one side the appearance of technological solutions for finishing of external surfaces of masonry by use of «artificial» stones (mainly craft and empiric experience realised outside theorisation of Academy), on the other fast substitution of wood with reinforced concrete in realisation of slabs (process happened, on the contrary, with direct involvement of Academy and industrial world).

A NEW BASE-MATERIAL: «ARTIFICIAL» STONE

 Desired and searched from past Architects, «artificial» stone finds, in the experimental fervour of considered period, its practical realisation in concrete applications, the «new» material at its best: its sudden birth, marvellous and apparently not thwarted spreading and us much fast disappearing is then exemplificative of fast evolitional processes of beginning of nineteenth century buildings.

Introduction of Portland cement at beginning of ‘800 and consequential fast progress of studies and production of different types allow placing in the market of a new base-material, an «artificial» stone made similar to natural and more expensive ones, often difficult to get due to distance of caves and/or difficulty of their extraction. Artificial stone, letting the designer free from bounding related to geographical placement an to displacement on the territory of natural elements, but also, and moreover, appearing not to be subject to precariousness of being natural with consequent lack of homogeneity and complication of manufacturing, becomes symbol of new progress performed by industrial society.

Then, during first decades of XX century a new technology develops which affects external surfaces of masonries, but also stairs, pavements, internal decorations, parapets and balconies, brackets and labels in a vertiginous process mainly founded upon products whose definition was the result of experiences performed with craft criteria but with proto-industrial production developments. It is an example, in Italy, fast development of Ghilardi Company, the first one to start cement handmade products: from first craft workshop on 1876 in Bergamo, in which production takes place by use of machines invented and optimised by Ing. Ghilardi himself, the company gets to four plants in Bergamo, Milano, Bari and Palermo in 1886.

Evident were the advantages of the new material: handmade of artificial stone appears as solid as marble, unalterable along use and as cheap as bricks. In pavement case, as an example, it has to be underlined their elegance (due to variety of sketches and colours) and moreover their healthiness (as they don’t generate dust and don’t adsorb humidity).

Evolution of artificial stone, very fast but also of a short duration, basically went on without direct involvement of Academy, left at margins of productive process, all founded upon empiricism.

Fast and definitive establishment of modern materials and techniques determines the end of short success stage of such technologies: the suddenly disappear together with men that produced them and with knowledge mainly derived from their experience.

FROM WOOD TO REINFORCED CONCRETE: RAPID EVOLUTION OF FLOORS

Evolutional path of building of beginning of nineteenth century starts, as said, with progressive introduction of
«modern» elements and materials in «traditional» techniques and technologies of building: substitution of stone natural elements with others of artificial kind, but moreover of structural elements (firstly flat arches, arches, vaults and wooden floors) with others made of iron, reinforced concrete and brick-concrete.

A demonstration is represented by introduction of iron reinforcing systems of floor wooden beams, used in case of excessive length and/or loads. Reinforcing systems documented in different Manuals (i.e. Cantalupi’s Manual (Cantalupi 1862)) are a multitude but the on «commonly adopted» (so defined by Formenti (Formenti 1893)) consists in connecting under wooden beam one or two punchers, respectively at middle or at the same distance from the middle point, and in placing under these a iron tie which is blocked at its edges to beam’s extremities in order to let this one, with its load, pull ties in tension; these avoid inflexion of beam with their resistance.

Iron frames already appear during middle of ‘800, even if their use is defined by Curioni (Curioni 1868) still «strictly limited» in Italy. Introduction of this new construction element, iron beam, is possible according to development of iron industry with consequential production of profiles made for specific use, to need for reducing risks provoked by fire, to extraordinary increase of cost of wood happened along middle of XIX century due to extensive use of it in railway construction, to possibility for reducing height of frames. Initially the use of iron bearing floors spread itself completed firstly by wooden slabs and then by little vaults made of natural or artificial blocks, by hollow clay block and by special bricks the «hollow flat blocks».

A multitude technological solutions of mixed floors in wood and iron, moreover with reference to connection between iron beams and wooden rafters (or slabs) and evident inconvenient determined by low compatibility between wood and iron: «And really, if we have the connection of iron elements with wooden beams by use of bolts which go across wood it is an easy probability that wood humidity generates rust on connecting iron». (Breymann 1895).

First example of mixed floors, made of iron beams and bricks, is represented within Curioni’s Manual (Curioni 1868), but it is in 1892 that first patent for iron beams and artificial plane slabs was obtained: they were Klein floors made of iron beams and slabs made of bricks and iron stripes. Figure 1. Figure 2.

Technical and technological solutions more and more assume characters of more complexity and articulation according to evolution of scientific studies and moreover of components which, as said, were born from industrial patents. An example is the case of use of hollow bricks, instead of full bricks, with two, three, four, six holes, or with special shape
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with one or more holes: each kiln uses particular shapes in order to obtain more lightness with more cords at same resistance.

Several are the advantages of iron and hollow brick floors: less dimensions (and then less total height of the building), lack of push on confining walls (which may have a minor thickness), more resistance («It has been showed that a floor made of I irons and little brick vaults has a five time resistance more than a floor made in the ordinary way by use of wood and that hollow brick floors are more resistent than full brick ones as first ones results to be more elastic» (Donghi 1905)), more durability and hygienic, less cost (as they were lighter and they required less section of beams and then less use of iron), more soundproofing (due to cavities within bricks). Figure 3.

Figure 3
An example of floor made of iron I beams and hollow bricks (Breymann 1895)

The experimental and innovative character of technological solution exposes at risk of initial uncertainty: floors made of iron beams an hollow flat bricks, in their first applications don’t seem to be safe against fire, as they don’t have their lower wing proofed from direct contact with fire. Breymann’s Manual (Breymann 1895) and Levi’s (Levi 1907) show, with many examples, the way Industry creates a remedial against such inconvenient by producing special impost bricks having a reception cavity for iron beam wing, which then results as covered and proofed against fire.

In parallel to mixed floors in iron and bricks, normally, mixed floors in iron and cement-based materials are used; they are realised with bearing elements made of iron I beams and fillings made in different modality: as an example the so-called «Parisian system», reported by Donghi (Donghi 1905), with rubbles, brick scraps, mortar, chalk and reinforcing irons or iron sheets (longitudinal or transversal) with upper concrete pouring already documented by Cantalupi (Cantalupi 1862). Figure 4, Figure 5.

Innovation realised by spreading of iron beams, in a construction process basically kept the same for centuries, doesn’t determine a modification of construction, technological, structural and functional conception of residential building complex in its whole (differently by industrial buildings case), as bearing vertical structure mainly remains the same. Architecture, both in new plan-volumetric aspects, in

Figure 4
An example of floor made of iron I beams and cement-based materials (Misuraca, Albertini and Boldi 1900)
internal distributive characters and in most formal ones, keeps being indifferent to transformation on run, as substitution process has origin in reasons of practical and economical opportunity without being recognised to modern materials and techniques a proper dignity and specificness that means a proper architectural «language».

Even connections between new ceilings and bearing walls basically reproduce traditional technological solutions already used for wooden floors: an example is represented by solutions documented by Levi (Levi 1907) and by Vivarelli (Vivarelli 1913) in which supports of iron I beams upon confining walls are made of «very hard stones» in order to split loads, or the connection I beam-wall obtained by use of master key or iron tie. Figure 6.

And moreover it is sufficient to think to diffuse felt necessity, in residential buildings, to use false ceilings to hide floors and reproduce aesthetic effect of vaulted ceilings. Such false ceilings are made up with complex and articulated technical solutions due to necessity of connection between materials and traditional technologies (as fillers and lathing) and other moderns as the one of «new» floors: an example is given by iron beams and concrete little vaults floor which wooden joints are connected to for the clinging of false ceiling filler proposed by Breymann (Breymann 1895).

Progressive introduction of reinforced concrete structure (happened on the base of intensive experiments, of tuning of static calculations, as much as of evident advantages connected to fire proofing features, of being a unique piece, of possible prefabrication, of resistance to earthquake and of different site organisation) doesn’t modify in the facts the described situation. In fact, initially, only substitution of iron ceilings with full slab reinforced concrete floors took place: Monier slabs (first application to buildings of studies on reinforced concrete), with reinforcement of round bars crossed and bounded with iron yarn, due to resistance, rapidity and ease of manufacturing are used in substitution of tile little vaults. Consequent numerous patented systems (Coignet, Hennebique, Cottacin, Coularow, Walser-Gerard, to indicate some) only differ according to placement of reinforcement bars and according to this, in order to avoid exclusivity of patents, numerous types «created» and use don site differ following a tradition which prefers practice to theory. Figure 7.
From analyses of different types clearly emerges that need and conditionings of traditional culture keep stay the same: these innovative solutions still provide supports on bearing walls and/or complex and articulated connection systems, as in the case, documented by Formenti (Formenti 1893) of Matrai floor, in which slab reinforcement is made of yarns and steel cables connected to masonry by use of hooks anchored with vertical stakes drowned in masonries themselves. Mentioned conditioning are not only to a technical-technological level but also to an aesthetic-typological one: an example is made by different solutions of reinforced concrete slab floors so-called air-room floors, which have to respond to mentioned aesthetic need of hiding eventual ribs or visible bearing elements by mean of plain false ceilings made of reinforced concrete and/or hollow flat bricks (Frazzi, Corradini systems). It is also this need that determines, after, studies and spreading of numerous kinds of floors made of concrete and artificial blocks.

The truth is that it is the structural and construction building conception that changes in a more or less conscious way for operators: more loads and strength of horizontal slabs, more efficient connections between horizontal and vertical structural elements, less capacity of the masonry structure to undertake light differential assessment, are only some of the new features of building complex.

Further evolution of studies and technological solutions, on one side, and functional needs, on the other, determines spreading of frame structures, which means the use of beams and pillars, in a first time only for substitution of main wall of buildings.

They are first application of Hennebique’s patents related to results of study on linear concrete elements, diffused all over Europe due to an advertising campaign and to a network of agents that show the «new» material as a marketing and not experimental product, characterised by precise requirements: lightness, resistance, cheapness, fireproof.

Construction conception is still related to traditional building in masonry: central frame structure is introduced as an independent sub-system, aimed to solve specific static problems, but without considering effects determined on building complex. This, by the way, has got to have an external covering which assures, also according to many building codes of that age, «an ordinary aspect» (Morsch 1930).

Only after long time, use of frame structure affects the whole of the building and advantages are receipted as much as possibility even to a distributive-functional level.

**CONCLUSIONS**

Buildings at beginning of nineteenth century, created and made by use of conjunction between techniques and materials deeply different according to substitution and overlapping process which to apparent and immediately perceiving positive effects puts beside contradictions and potential «aspects of crisis», is subjected to an aging process ascribable to a material and «technological» decay and to a not less important «typological aging» referable to organisation and distribution of internal spaces.

The research, still on run, allows systematisation of a knowledge which constitutes the preparatory phase to analyses of decaying process of such building heritage. Starting from the study of technical-construction features of masonry structures and of transformation when substituting materials and traditional construction elements with modern ones,
next stage is to locate potential lacking point where decay phenomenon can generate under technical, construction, functional, typological and code profile.

This in order to define specific methodologies and guidelines, procedures and operative proposals aimed to maintenance, conservation and requalification for restoration of performance quality of building of beginning of nineteenth century.

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