1. INTRODUCTION: EXPERIMENTATION WITH THE METAL ROOFS OF PALERMO’S THEATRES

The years straddling the mid-19th century are among the most stimulating for anybody interested in exploring building methods from the recent past, in seeking the technical rationale, examining the evolution, monitoring utopia and failure. The developments in studies of building materials and the functional, technological and formal aspects of architectural construction, especially in Anglophone and Francophone areas, subsequently spread to every corner of the Western world, propelled by the publicity emerging from the great Exhibitions. The rapid diffusion of information in those years contributed to spreading ideas about new materials and technology; these transformations were sustained in other countries by industrialization in full flow, and found limited opportunities for application in Palermo in the local
productive context, which embraced little more than hand-crafts. However, local society was culturally active and the construction of large iron structures, such as markets and theatres, made a considerable impression in terms of publicity on the local technical and, especially, academic scene. University lectures, in particular those given by G.B.F. Basile, now envisaged detailed study and calculation for complex metal roofs characterizing this new type of building spreading throughout Europe (stock exchanges, railway stations, opera-houses), in which monumental aspects were combined with innovative technical solutions, with iron and cast-iron playing a leading role.

Covered markets were certainly built, exposing large quantities of metal, but it can safely be said that the greatest impact was produced by theatres and opera-houses, although iron structures were hidden from view (in the roof-works) or even inserted inside the floorings. The theatre was considered a historic building in every sense, and therefore a highly representative element, whereas markets represented functional consumer-oriented objects. Although Basile’s Teatro Massimo and G. Damiani Almeyda’s Politeama were similar in purpose, size and period of construction, they differ profoundly as regards the metal roofs over the stalls area, the specific features being complex, innovative and strictly technological. However, both seem to have shared several typical solutions as regards the structure and roofing over the stage. The latter was defined by the designer of the Politeama as a common example of construction in iron; he was probably referring to the treatise by C. Eck (1841), containing examples of the construction of arched frameworks, which were rather similar as regards the shape and geometry of the beams.

Figure 1. Perspectival view of the roofing of the Politeama stalls area.
In the same way, the coherent structure of the Teatro Massimo stage looks surprisingly similar, in terms of shape, relative size and functioning profile, to the “French system” as published by Contant and De Filippi (J. De Filippi, *Parallele des principaux theatres modernes de l’Europe et des machines theatrales francaises, allemandes*, Parigi, 1860); there was no trace of any structural calculations, which was not the case for other metal parts. The roof over the stalls area of the Politeama measured about 1,200 sq. m; it was added a few years later to a structure that was originally conceived as a day-time theatre. Damiani tackled the structural problem by linking it to the problem of natural light and ventilation. More specifically, the overall conception of the structure was aimed at reducing the distance between the external roof and the ceiling in the stalls area, moulding the shape of the intrados of the large metal arches (making up the structure) to the shape of the internal vaulting. At the same time, the extrados was shaped in such a way as to also become a support for the conical external roof. The roofing structure was basically made up of two parts: a central cupola with an elliptical base, flattened and provided with a little lantern. The former, at one end, rests on a large elliptical ring (*ellisse di gola*) supported by 16 cast-iron columns; these are linked to the rotation surface, which constitutes the roofing of the first *cavea*.
The complexity of the structural solution had to take into account the reality of the level of craftsmanship, but even more fraught was the young engineer’s relationship with the limitations of the scientific community, which had not kept up-to-date and had never ventured on an operation of this size. A specifically nominated Commission did not approve the structure calculated with an *elegant, new, ready and delicately exact graphic-static method*, the scale model of which was ironically defined by some as a *fair-ground toy* [...]*lacking any mechanical concept* (Damiani M., 2001). It was feared that the effect of possible deformations in an iron structure 42 metres long, might not only lead to the collapse of the roof but also of the 25-metre-high walls. A *most favourable and acclamatory* opinion was obtained from Alfredo Cottrau, a renowned expert in iron construction, to whom Damiani had secretly sent the design for examination, and this condition led to the approval of the design by the Commission; however, further tests were requested from the Prussian engineer Theis, manager of the Oretea foundry, with the additional assurance that the foundry itself would assume the responsibility of carrying out the work for the success of the enterprise. In 1877 the roof was completed and the design received words of appreciation from architects such as Daly, Durm and Collignon (Pollaci Nuccio, 1892).

The episode regarding the metal structures of the Teatro Massimo bears witness to the inertia that continued, even after a few years, to plague the local technical community. From the first drafts of the design Basile showed himself to be a confirmed upholder of the use of iron in roofing and ceilings, with the application of the most evolved and up-to-date building methods existing at that time. More specifically he was convinced of the superiority of the floorings in the *poteries et fer* (earthenware and iron) building approach, as championed by Eck and widely applied in north-eastern Europe, especially in a type of building in which fire-proofing and sound-proofing represented requisites of primary importance. We know that for a surface larger than the 22,000 sq. m of the floorings of the theatre, a structure in earthenware and iron was envisaged, a technique that had never been applied up to that time in Palermo and which Basile intended to experiment directly and then popularize.

Basile’s visits to the *Universal Exhibition* in Paris in 1867 and 1878 (on the latter occasion as the official delegate for the Italian state and designer of the national pavilion) enabled him to come into direct contact with the state-of-the-art technicians and producers, and contributed to shaping his technological awareness with regard to the potential of iron. Between the initial plans and the commencement of operations, in a period of about 8 to come teatro diurno, Damiani affrontò il problema strutturale associandolo a quello dell’illuminazione naturale e dell’aerazione; in particolare, la concezione generale della carpenteria fu improntata a ridurre la distanza tra copertura esterna ed il piano della sala, sugandolo l’intradosso degli archi metallici che costituivano la struttura secondo la conformazione della volta interna. Al contempo, l’estradosso fu configurato in maniera da diventare appoggio anche per la copertura conica esterna. La struttura di copertura è composta essenzialmente da due parti: una cupola centrale a base ellittica, schiacciata e provvista di lanternino, poggiata all’estremità interna di un grande anello (ellisse di gola) sostenuto da 16 colonne in ghisa, a cui si collega la superficie di rotazione che costituisce la porzione di copertura della prima cavea. La complessità della soluzione strutturale dovette adeguarsi alla realtà produttiva di livello artigianale, ma ancor più difficile fu il rapporto del giovane ingegnere col limitato aggiornamento dell’ambiente scientifico che mai si era cimentato in un’opera di queste dimensioni. Una Commissione appositamente nominata non ritenne di approvare la struttura calcolata col nuovo metodo della grafostatica, elegante, pronto e delicatamente esatto, il cui modello in scala da alcuni era ironicamente definito un giocattolo da fiera [...].

La copertura venne ultimata ed il progetto affinché lo esaminasse, consentirà l’approvazione dello stesso da parte della Commissione, nonostante venisse richiesta un’ulteriore verifica da parte dell’ingegnere prussiano Theis, direttore della fonderia Oretea che avrebbe eseguito l’opera, e l’assicurazione che la fonderia stessa si sarebbe assunta la responsabilità della riuscita dell’opera. Nel 1877 la copertura venne ultimata ed il progetto ricevette importanti apprezzamenti anche da architetti come Daly, Durm e Collignon (Pollaci Nuccio, 1892). Anche le vicende delle strutture metalliche del Teatro Massimo testimoniano l’inserza che continuava a caratterizzarsi, a distanza di qualche anno, l’ambiente tecnico locale. Già nella fase dell’elaborazione del progetto Basile si mostrò un convinto asettore dell’uso del ferro per coperture e solai, con l’applicazione dei sistemi costruttivi in quel momento più evoluti ed aggiornati: in particolare si era allora lasciato convincere della superiorità del sistema costruttivo degli orizzontamenti in poteries et fer (vasellame e ferro) divulgato da Eck e diffusamente applicato in area nord-europea, specie in un tipo edificio in cui l’incombustibilità e l’isolamento acustico costituivano requisiti di primaria importanza. Sappiamo che per una superficie maggiore di 2000 mq i solai del Massimo erano previsti con struttura in ferro-vasellame, tecnica mai fino allora utilizzata nella città e che Basile si progettava di sperimentare direttamente e divulgare.
10 years, which bore witness to rapid French, English and German technical-scientific progress (almost always filtered through French publications), Basile, with the construction of his opera-house, managed to attain a level of quality comparable to the great opera-houses of Europe. He contributed to the definitive introduction of ferro-vitreous art on the Palermo scene, although, in this classic emblematic monument, the complex and Piranesian metallic frameworks had to remain concealed.

Furthermore, especially for floorings and roofs, including those of a large size, calculation was no longer deemed necessary. Since by the 1850s the producers themselves and specialized journals published charts and tables with advice about the type of iron to use in function of span and acting load. The 1878 Paris Exhibition displayed a certain homogeneity in the size of industrially produced sections, with catalogues capable of resolving all current building problems. One of these must have been the Album Jacquemin mentioned several times by Basile in the service orders for his works, to which the building firm had to refer for the sizing of the iron. The general substitution of systems using frameworks, crossbeams and earthenware, by section iron structures was not so much a change of direction as new systems conforming to the ulterior innovations that had replaced what had, in a short time, become an obsolete technique.

Although Basile seemed to be extremely confident of the new building quasi sempre filtrati da pubblicazioni francesi, Basile conseguirà con la realizzazione del suo teatro lirico un livello qualitativo rapportabile ai maggiori teatri d'Europa e contribuirà al lancio definitivo della ferro-vitreous art nell'ambiente palermitano, per quanto in un monumento emblematica della classicità, le complesse e "piranesiane" membrature metalliche dovessero comunque rimanere occultate. Inoltre, soprattutto per i solai e le coperture, anche di grandi dimensioni, il calcolo non era considerato più necessario in quanto già negli anni '50 gli stessi produttori e le riviste specializzate pubblicavano abachi e tabelle con le indicazioni dei ferri da adoperare in funzione delle luci e dei carichi agenti. L'Esposizione parigina del 1878 mostra una certa unificazione delle dimensioni dei profili prodotti dall'industria, con cataloghi in grado di risolvere i problemi costruttivi correnti. E appunto uno di questi doveva essere quell'Album Jacquemin richiamato più volte da Basile negli ordini di servizio delle opere, a cui l'impresa doveva riferirsi per il dimensionamento dei ferri. La sostituzione generalizzata del
methods, he was probably less optimistic with regard to the material used: iron, and, even more so, steel, possessed unpredictable characteristics, to the extent that, with regard to floorings, he felt that he had to improve the quality and the resistance of the H-beams coming from the best European factories; as a “greater guarantee”, he applied ulterior “forge fatigue” (fatica di forgia) to these beams, before employing a framework that was to undergo the greatest stress. The roofing for the stalls area of the Massimo, a metal cupola of a diameter of about 28 metres, represented without doubt a demanding and innovative feat, even in the context of the international scene. Basile applied a static method that had been widely-known for at least ten years, using a system of approximate sizing (published by W. Schwedler, 1877), which consented a considerable lightening of the framework, a more rapid production of the components at the Fonderia Oretea and rather easy assembly for the workforce. Charles Garnier had just completed the Paris Opéra and when asked for his opinion by Basile, who was eager for authoritative confirmation regarding the static aspects and the calculation of the elements of the roofing over the stalls area, he replied with a letter in which, diversely from Basile, he declared himself incompetent with regard to technical issues.

2. METAL STRUCTURES IN COVERED FOOD-MARKETS

Free from aesthetic and symbolic conditioning, covered markets triggered a debate that was fuelled, on the one hand, by the widespread enthusiasm for the Les Halles in Paris, and, in general, for iron and glass architecture, and on
the other hand, by doubts for aesthetic, environmental comfort and economic reasons. This rush to endow the city with functional and up-to-date commercial structures was countered by the many voices raised in protest at the decision to imitate foreign models, especially when their profound defects had been widely acknowledged. The large glass surfaces were gradually replaced by zinc slabs, for customer comfort and because of the problems caused for the food-stuff; Baltard himself, designer of Les Halles, had considered it a mistake to simply re-propose the model in other areas having very different climates: [...] to foreign builders, from north and south, who have consulted us, we have repeated time and again and we restate it here, that, as regards a particular lay-out of the Paris building, if it is predisposed to imitation, one must first of all consider, which is obvious, the climate in which one is building and the material that is available [...]. Furthermore, when the ultimate goal was to achieve eurhythm in artistic embellishment, one had to bear in mind the high costs of metals and their working, without forgetting that these new materials could neither replace, nor integrate stone.

It was with these premises in 1867, as part of a vast Project for topographic and decorative reform, that a large covered fish-market with a metal roof was contracted and quickly built near the port, following a project by Giuseppe Damiani. Although the size (61.80 x 24 ml) was rather small when compared to other Italian and foreign examples, this market did represent a sort of pilot-scheme. The great venture with the two theatres was to start shortly and this was the first time that an architect, in collaboration with local producers, was tackling the planning and construction of a metal building of some considerable size.

The paved floor over the basement, which housed the storerooms, was entirely covered by a metal roof, supported by 40 slim, hollow, cast-iron columns laid out in four rows, with an inter-axis of 6.30 ml. Apart from locally-produced metal elements, the project envisaged the use of the best materials existing on the market; the idea was to use “special iron beams” or “strained beams” (ferri tirati) ordered from the French workshops of Zorès, who could not honour the commitment at that time because the firm had gone bankrupt. These beams had only been used for a few years in France and were made in a variety of sections and sizes by a restricted number of iron and steel companies; the most widely-known of these was in fact the Ferdinand Zorès firm, which was renowned for the building system of what were known as Zorès iron bridges, of which there are many remaining examples in several parts of Europe. This entrepreneur was also famous for having patented and produced in the mid-1840s the characteristic Omega section bars (Ω), which carried the name of les Halles parigine ed in generale per le architetture in ferro e vetro, dall’altro da dubbi per ragioni estetiche, ambientali ed economiche. Insieme ad una rincorsa per dotare la città di strutture commerciali funzionali ed aggiornate, molte voci criticavano la scelta di imitare i modelli stranieri quando già in sé non erano riconosciuti i profondi difetti. Per gli incomprensioni provocati alle derivate ed al conforto degli utenti, le ampie superfici veritate si andavano sostituendo con lastre di zinco, e lo stesso Baltard, progettista delle Halles, aveva considerato un errore la semplice riproposizione del modello in altre aree dal clima assimilato diverse: [...] ai costruttori stranieri, del nord e del mezzodì che ci hanno consultato abbiamo ripetuto a sazià e lo torniamo a dire qui che certe disposizioni dell’edificio parigino, se sono sussistibili di essere imitate, si deve prima di tutto, il che è elementare, pensare al clima nel quale si costruisce, ed al materiale di cui si dispone [...]. Inoltre bisognava tenere conto dei costi molto alti dei materiali metallici e delle loro lavorazione, senza dimenticare che questi nuovi materiali non potevano sostituire, ma neppure integrare la pietra quando l’obiettivo era la ricerca di congruenza nella decorazione artistica. Con queste premesse nel 1867, nell’ambito di un vasto “Progetto di riforme topografiche e decorative” venne appaltato e rapidamente realizzato un mercato ittico coperto con tettoia metallica su progetto di Damiani in prossimità del porto. Seppure di dimensioni ridotte rispetto ad altri esempi italiani ed esteri (61,80x24ml), questo mercato rappresentò una sorta di “progetto pilota”. Per la prima volta – l’esperienza dei due grandi teatri sarebbe iniziata da lì a poco - un progettista e una realtà produttiva locale si confrontavano con la progettazione e la realizzazione di una costruzione metallica di grandi dimensioni.

Il piano lastricato di copertura del corpo seminterrato, che ospitava i magazzini, era interamente coperto da una tettoia metallica, sorretta da 40 esili colonne cave in ghisa disposte su quattro file, con interasse di 6,30 ml. Oltre agli elementi metallici prodotti localmente, il progetto prevedeva l’uso dei migliori prodotti esistenti sul mercato: si fa qui riferimento ai “ferri speciali” o “ferri tirati” richiesti alle officine francesi Zorès che non furono in grado di fornire all’appalto le ampie superfici vetrate che certe disposizioni dell’edificio sottoposti alla ulteriore “fatica del Novecento. A sottolineare una considerazione: [...], che in base a quanto detto abbiamo già detto e che ora ripetiamo, non si trattava di semplici riproduzioni di modelli stranieri, che certe disposizioni dell’edificio sarebbero state imitate e che un semplice ripensamento alla decorazione artistica avrebbe potuto riuscirci. Oltre al clima, che certe disposizioni dell’edificio dovevano essere considerate come una sorta di “progetto pilota”. Per la prima volta – l’esperienza dei due grandi teatri sarebbe iniziata da lì a poco - un progettista e una realtà produttiva locale si confrontavano con la progettazione e la realizzazione di una costruzione metallica di grandi dimensioni.

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the inventor himself and appeared in the catalogues of many other firms right up to the early years of the 20th century. To underline the limited confidence in these products, the industrial section beams (of any provenance) used in the “fish-market” were also subjected to ulterior “forge fatigue”, for a greater guarantee of quality, homogeneity and resistance. Obviously, the mixing, in the market building, of industrial elements with hand-made products, entailed continual operational changes and adjustments, such as the inserting of the large roof arches on to the tops of the cast-iron columns using a cylindrical axis of wrought-iron, strained and perfectly axial with the column. Further expedients of a handicraft type were applied in areas of contact between cast iron and bar (b) iron, in which, in order to forestall possible phenomena of rapid oxidisation, a few surface sections of the central axes were subjected to tin-plating. A longitudinal incision was made in these, filling the cut itself with lightly compressed earth, to consent the expected shrinking of the cast-iron during the cooling phase. These and other “fusion soils” were easily eliminated once hardening had set in, the necessary empty parts thus being reconstituted.

A few years after the inauguration, in spite of the quality of the architecture and the planning care devoted to interior lighting and ventilation, to the construction of an actual “ventilated roof” and the attention paid to hygienic aspects, sources report a total lack of interest on the part of local people, who

![Figure 5. Structural elements of the roof of Damiani's fish-market.](image-url)
were more used to the disorder of street markets. This led to the abandoning and, eventually, the destruction of the market following a fire in 1889.

As further proof of the development of planning and technological skills, in a social environment that was not quite ready, mention of the food market in Piazza degli Aragonesi should be made, it being completed in 1874 from a project by the same architect Giuseppe Damiani. This market constitutes an emblematic example of how technical and cultural renewal fostered the re-examination and adaptation, in function of a more correct adjustment to the local context, of an initial model of a covered market of clear “foreign” derivation.

In the first project, which was subsequently modified as regards the number of spans, 36 cast-iron columns and a further 28 columns of moulded iron, were positioned in the second order, creating an arrangement of three spans on the short side and eight on the longer side, connected at the top by iron beams and large arches. These columns supported the metal roof, which was divided into two distinct parts. A symmetrical, double-pitched roof was aligned at a lower level, following a continuous ring-shaped trend in corresponding position to the outermost part of the market. Whereas the central portion, the lantern, also had the form of a symmetrical, double-pitched roof, it was constructed at a higher level so as to provide for an unrestricted, horizontal slit capable of guaranteeing a certain amount of light in the darkest corners, as well as good natural ventilation.
The same system had already been adopted for the fish-market. The proposed roof consisted of trusses and a roofing frame in wrought-iron; it was topped off with boards, and a surface layer of zinc-foil from the Vieille Montagne factory in Liege. This was not a casual choice, but further proof of the high quality that Damiani demanded, also in terms of the best available materials, such as the zinc from the Belgian factory; the brand-name VMZINC is still today an important point of reference for laminated zinc. Perhaps bearing in mind the doubts being raised, and diversely from the reference models, the use of glass was not envisaged in any part of the roofing in the executive project; the light entering both from the side walls and the slit between the roofs at different heights was deemed sufficient. A contract was stipulated with the Naples firm of Guppy e Compagni Engineers, for supply of the metal framework, in accordance with the executive designs by Damiani of the structural and decorative elements of the new market’s roof. Also in this case, the choice fell upon a well-qualified factory that had for some time assumed leadership of the Italian iron and steel sector. In 1870 this firm took on the assignment of constructing the metal structures for the three covered markets in the city of Florence; the project was by Giuseppe Mengoni, who in those years had competed his most famous work, the Galleria Vittorio Emanuele in Milan. Like nearly all engineers at that time Mengoni preferred to employ, for even the most complex metal structures, soft puddling iron, rather than steel, which at the end of the 1860s was being produced in small quantities and was expensive and of unreliable character. Gustave Eiffel himself, at that time, was building structures for bridges using wrought-iron, and continued to do so throughout the 1880s, in spite of the great advances in steel production and technology; these included the famous tower for the Paris Exhibition of 1889, whereas the Galerie des Machines was built using steel. Mention should be made of the economic interest Eiffel had as a shareholder in the Pompey ironworks, which only built and activated a Martin furnace to produce steel in 1888. An album discovered at the Historical Archive of Palermo city council enables one to observe in detail the executive designs for the principal structural elements making up the complex metal structure; they had been edited by the Technical Office of the above-mentioned Società Guppy, with the exact dimensions and technical terms employed to identify the various parts. It is not known whether the components were actually constructed in the Naples factory or, as seems to have happened with the roofing for the Florence markets, at the Belgian factories […] certainly not because they were not capable of constructing them, but to avoid certain taxes that had been unexpectedly levied on the importation of raw materials […].
The eight years between the initial conception and the completed work witnessed the maturing of knowledge regarding the adaptability of market typology to the local environmental conditions, abetted by the experience being acquired and diffused throughout Europe. Whereas total lateral closure with wooden shutters was envisaged for the fish-market, which was under construction at the time, for the other commercial structure (i.e. the food-market) Damiani acknowledged the need to introduce substantial changes to the initial project, in order to align it with a second version that better suited the environmental conditions of a Mediterranean city and the general feelings of the local community. The original open-sided roofing was partially sealed along the external perimeter with a series of brick workshops, structurally autonomous and separated by over a metre from the lower edge of the roof.

Despite the very accurate design, the economic commitment and the fruitless attempts to involve vendors and customers, a little over ten years after completion, the municipal administration was obliged to close down the market in Piazza degli Aragonesi; over the years it had undergone many transformations and alterations but was, in the end, dismantled.

The technical, structural, hygienic and distributive aspects satisfied the inspectors, but did not pass the test of social acceptance, the most demanding and difficult test of all.

3. CONCLUSIONS

The second half of the nineteenth century, relating to a more extended...
geographical ambit, is marked by the rapid technological change and the spread of new materials, able to support the innovation of architecture and of its construction: among them, a central role is to be assigned to the iron for its static and aesthetic values, consequently to the development of steel industry, that assume an industrial dimension after a traditional craft roles, also permeating at different speeds the most marginal areas in Europe.

The metal construction of the roofing of the main theatres of Palermo, as well as the markets, is a significant example: the long distance between design and manufacturing allows us to verify the technological evolution and the critical adaptability of models applied in other Countries. The dissemination of knowledge, favoured by the movement of technical journals and international Exhibitions, produced an updated knowledge of the technicians, even in geographically remote and industrially less developed areas. This promoted and consolidated a fruitful cultural exchange between the designer, with the circulation of the updated calculation systems of complex structures, but also a strong and healthy competition between the production companies that made easier the work by offering speedy tables for the design of simple frames. Clear examples are the judgment requests or simple advice to C. Garnier and A. Cottrau, as well as the supplies of building materials to the important iron and steel production workshop like the French Zorés and Guppy of Naples for the steel structures, and the Belgian Vieille Montagne for semi-finished zinc.

6. REFERENCES

[1] Damiani family archive
[2] Historical Archive of Palermo city council