Introduction

There is a close and sometimes bewildering relationship between cast iron used as architectural ornament and cast iron used as a structural material — indeed, in many buildings cast iron performs both roles simultaneously. This paper concentrates on the documentation concerns associated with restoring a building clad with cast iron. It presents an engineer’s perspective of the structural issues associated with preparing and utilizing such documentation.

Three principal technical aspects of the restoration of cast iron influence the preparation of drawings and specifications. These are identifying the component materials of which the building is constructed, including both the cladding and the underlying structural frame; recording the existing condition and construction details of the original cast-iron elements (whether they be architectural or structural in nature or both); and specifying new structural members that will mesh with existing elements.

To illustrate these three points this text presents examples from two buildings in Manhattan with significant amounts of exterior cast-iron cladding — the Battery Maritime Building and 101 Spring Street.

The Battery Maritime Building is a steel-framed Beaux-Arts landmark that was constructed as a ferry terminal and completed in 1909. It served as the Manhattan home for ferry service to Brooklyn until 1938. Since 1956 it has served as the base for ferry service to Governor’s Island. The cladding includes more than 5,000 pieces of cast iron, as well as large amounts of plate steel (as decorative elements), glazed ceramics, sheet metal, and stucco (Fig. 1).

Number 101 Spring Street is a five-story building designed by Nicholas Whyte in 1870; built to serve commercial and industrial needs. The artist Donald Judd moved into the building in 1968; today it serves as the New York home of the Judd Foundation (Fig. 2).

The building is set within the SoHo Cast Iron Historic District — one of the largest assemblages of such buildings in the world. The exterior cast-iron columns are structural; other structural elements, such as cast-iron spandrel beams, wood girders and joists, load-bearing masonry walls, and the foundations, are hidden behind architectural finishes.

Visual Assessment and Probing

Learning to understand the different functions of cast iron as architecture and cast iron as structure can help determine what to document as part of the restoration project. Knowledge of the material properties, typical original construction details, and weathering characteristics can help guide the engineer in evaluating the performance of cast iron as structural members. The methodology described here has been developed over time by combining the experience of structural engineers on various cast-iron restoration projects with the code requirements for the structural analysis of existing buildings. The specifics of this methodology may vary from building to building and from locale to locale; this description is intended to be a general guide. The detailed assessment of each building requires the combined efforts of a registered architect, a licensed professional engineer, and other related consultants (including materials-testing consultants). The best results have been achieved by a careful review among the structural engineer, the architect, and the owner of which types of assessment are needed at the beginning of the project.
As part of the documentation of existing conditions, it is important to locate and identify each of the different types of structural members and how they are connected to each other in plan, section, and elevation. An initial assessment should be made to determine if the existing cast iron functions primarily solely as architectural cladding, such as at the Battery Maritime Building, or also provides important structural support, such as at 101 Spring Street. At the Battery Maritime Building a partial set of original structural drawings was available; they showed most of the columns and many of the beams, both along the exterior and within the interior of the building; they verified that the building had a structural-steel frame that supported the exterior cladding (Fig. 3).

Examination of historic drawings allows the structural engineer to figure out which structural elements are accurately depicted (reflecting as-built conditions) and helps the engineer decide which will need to be found and measured. Because of limited physical access, as well as budget and time constraints, the structural engineer will likely not see a large portion of the building exposed until construction and related removals are underway. Even during construction, much of the building’s structural fabric may remain hidden (since most building restorations do not include substantial removal of exterior cast-iron cladding). Thus one of the most important decisions to be made by the structural engineer is what must be field verified prior to the start of construction and recorded during the investigation phase.

Original architectural plans may show columns without showing the actual size of the members that make up such columns. What is often missing from original documents, including structural drawings, are the details of how principal structural elements are connected and how exterior cladding units are supported by structural members such as columns and spandrel beams. Further details, such as smaller hangers, brackets, and angles that support individual cast-iron units, are infrequently called out and delineated on original drawings. If a restoration team is particularly lucky, one might find some structural shop drawings that identify how the main structural members were connected. Original drawings showing how cast-iron pieces were attached are very rare indeed.

Within the limits of information available on historic drawings and the proposed scope of work, the restoration architect and the structural engineer must decide how much of the original building must be documented in order to fully describe the scope of repairs that are to be undertaken. The design team must document the different types of materials on a facade, the dimensions of connected parts, and the condition of the individual members. Figure 4 provides a typical drawing documenting the probing removal of cast-iron cladding.

In concert with the review of available historic documents (original drawings and specifications, photographs documenting the construction, reports of earlier surveys and inspections), the architect and the structural engineer should begin a visual condition assessment on site. Signs of distress, damage, and other areas of potential concern will be identified during this initial phase of survey work. The extent and type of deterioration should be mapped on the building in elevation and plan to see if there are correlations between the types of damage and the as-built detailing of the building element. For example, if there is consistent deterioration of the fasteners that secure exterior cladding units, one must determine if there may be problems related to the original construction. Issues that may be of concern are poor water drainage, lack of adequate corrosion-inhibiting paint, freeze-thaw damage, excessive jacking pressure from rusting, overstress due to inadequate fasteners or loss of fasteners, or poor choice of materials (such that galvanic corrosion may occur).

As the assessment is underway, the structural engineer must determine where sufficient information about the condition and construction details of the structural system is lacking. Even if original drawings exist, it often quickly becomes apparent that there is significant variation between the drawings and the as-built conditions. In such cases it is critical to recommend further field exploration to the building’s owner.

Also at this stage of the investigation, a preliminary structural analysis of the loads and forces within the building can be beneficial. For example, load “take offs” of the dead loads from floors, ceilings, interior partitions, mechanical systems, and other permanent loads can be computed. Live loads, such as occupancy loads on floors, snow loads on roofs, and wind loads on the exterior, should be calculated and evaluated in accordance with the load requirements of the building code that governs the evaluation of existing buildings. This preliminary analysis will reveal the
approximate loads in columns, major beams, and the foundations.

The structural engineer can then evaluate the potential capacity of typical members versus the approximate calculated loads. This information can help to determine which elements are more likely to be heavily loaded or, perhaps, overstressed if significant loss of material section occurs. There will undoubtedly be missing information about the actual members for at least some of the building — for example, the exact size of members, the size and orientation of connections, and the actual condition of suspect members. Within the limits of such a preliminary analysis, the structural engineer can identify the initial set of structural members that must be more thoroughly probed, documented, and analyzed.

When specific areas are identified as needing investigation, it is best to request probes to explore these areas. Probes can include the simple removal of small pieces of cast iron from the exterior; use of video or still-photograph borescopes, usually inserted through small holes in the exterior cladding or interior architectural fabric; or the more extensive removal of building fabric to see hidden internal structural elements. Written specifications, or a “probe package,” must be developed to describe the extent of the proposed temporary removal of fabric, the specific area requiring viewing, the general guidelines and precautions associated with such work, and the associated temporary repairs until permanent repairs can be made during the course of restoration work. In addition to the use of probes that temporarily remove sections of the cladding, the engineer may also make use of several nondestructive evaluation techniques. These analyses include ultrasound to determine the thickness of cast-iron elements (this is particularly useful in the measurement of “closed” sections or inaccessible members, such as columns) and infrared thermography to indicate areas where moisture is concentrating on the exterior of a building.

As noted above, some pieces of cast iron serve primarily as architectural ornamentation, such as cladding, and some serve a structural role, such as the columns that transfer vertical loads. In the case of the Battery Maritime Building, the exterior cast iron served almost purely as cladding to protect the interior of the building from the weather and to create some of the primary architectural attributes of the facade. At 101 Spring Street the exterior cast iron served as both the cladding to keep the interior protected from the elements and as an exoskeleton that provided additional bracing for and connections between the primary cast-iron columns and spandrel beams.

The documents produced during the probing phase may include hand sketches produced in the field and CAD-drafted drawings. Since the original field notes and photographs of site conditions are especially valuable when transferring dimension sketches into full CAD documentation, they should be carefully labeled and cataloged. Laser-dimensional surveys can also be utilized to develop two- and three-dimensional models of building elements — especially elevations and plan layouts of floors. It is critical to remember that such surveys do not necessarily depict structural members (e.g., columns or spandrel beams) that are hidden behind architectural surfaces. Careful measurement and depiction of these types of members require additional work by the survey team and the other design-team members.

Fig. 3. Partial plan view of the Battery Maritime Building showing the underlying structural materials beneath the exterior facade. Illustration courtesy Robert Silman Associates.
Of course, the documentation produced for internal use by the design team and as part of external reports to the owner must be presented in a clear, well-thought-out system. A well-planned system of numbering and cataloging cast-iron units is invaluable to the contractors during the bidding phase and subsequently during the preparation of shop drawings. At the Battery Maritime Building, the cataloging system of piece types, dimensions, location, and material condition created by the architects allowed the entire team to keep the more than 5,000 pieces of cast iron carefully identified and treated as individual elements.

All probes should be consecutively numbered, keyed to elevation and plan drawings, and fully dimensioned. (Figure 4 shows a typical CAD-drafted probe drawing illustrating a partial view of a structural connection at 101 Spring Street.) The probe documentation should illustrate the area of concern in plan, section, and elevation, as required. In especially complicated areas, carefully drawn axonometric drawings can be valuable in illustrating tricky or detailed connections (Fig. 5). This type of drawing can be especially helpful to visualize unusual or partially hidden portions of the building. Axonometrics can often be used to plan the sequence and the approach to installing structural repairs and reinstallation of the cast-iron cladding units.

Special Stability Considerations

When considering the removal of cast-iron elements during a probing phase or during regular construction-phase activities, it is especially important to consider the potential effect of removing specific pieces from the building. For example, if the cast iron appears to be a decorative element, one must ask whether the unit serves to brace or provide support for any adjacent pieces of cast iron. Indeed, it is possible that just such a piece is actually supporting parts of a floor or other portions of the façade, such as immediately adjacent pieces of cast iron.

If the removal of large sections of cast-iron cladding is anticipated, a structural engineer should be hired by the probing or general contractor to plan the temporary bracing or shoring up of the elements that may be affected by such work. Such shoring and bracing should be designed in advance of undertaking the work. The engineer and architect of record must review the designs for temporary shoring and bracing for their potential impact on the building, including whether the proposed work could affect the local or global stability of the building — that is, the support of just a single unit of cast material or the overall stability of the building.

If especially large amounts of cast iron are to be removed during the construction process, the stability of the building should be inspected and re-viewed periodically by a licensed professional engineer hired directly by the owner. While some jurisdictions, such as New York City, require such examination and review as part of the “Special Inspections” during the construction-phase activities, this inspection is not always a standard requirement. This level of inspection should be performed whenever the removal, repair, or replacement of load-bearing elements may be occurring or whenever temporary shoring or bracing is being installed.

In the case of 101 Spring Street, the exterior scaffold system was designed not only to provide access but to provide lateral bracing to the exterior cast-iron frame (columns and spandrel beams) during the course of removals and reconstruction of the exterior cast-iron cladding. Particular attention was paid to the possibility of hidden deterioration, especially in the form of missing fasteners or broken connections, that could temporarily weaken the building. The exterior scaffold provided greater structural redundancy during the construction in case such conditions were revealed.

While not a concern at either 101 Spring Street or the Battery Maritime Building, an additional issue to be reviewed by structural engineers and one which can be revealed if pre-construction documentation is done carefully is the presence of any settlement of the foundation. Such settlement could con-
Moreover, required consideration of how such work would temporarily or permanently affect the structural performance of the columns both locally and globally as part of the overall load-resisting frame of the building.

At 101 Spring Street the evaluation of such primary elements as the columns and the spandrel beams, which were located behind the exterior cast-iron cladding units, included verification of the connections between the columns and the spandrel beams. Where required, structural repairs to these connections were undertaken. As Robert Bates notes in his article describing the overall restoration of 101 Spring Street, the repairs included removal of the exterior cladding panels that cover the topmost portions of the columns. In this instance the cladding helped to provide additional lateral stiffness to the columns. Upon reinstallation of the cladding, the original effectiveness of this connection was re-established.

In the case of both 101 Spring Street and the Battery Maritime Building, structural engineers reviewed the results of the subsequent mathematical analysis and the results from the probes and other tests. The primary result of this work was the delineation of the actual areas of the building (including the facade and the other building elements) requiring structural repairs. In each case the significance of these findings was discussed with the architect and the owner.

Following review of these findings, details for localized structural repairs and for the addition of supplemental members were further developed. The various goals of the owner and the architect were considered when creating the list of structural repairs. Important goals in any project include mitigating potential hazardous conditions and making the repairs as durable as possible. At 101 Spring Street all new fasteners that supported or attached pieces of the exterior cast-iron cladding were made of stainless steel (Fig. 6).

The documents relating to the structural design (plans, sections, details, notes, and specifications) must fully record the new structural elements and illustrate how they will be integrated with the existing materials. For example, it is key that the new details illustrate all of the supports from the exterior cladding units back to primary structure (e.g., columns, spandrel beams, floor...
girders, etc.). Then the provision of detailed connection drawings may be completed; such details should include description of needed welds, bolts, and related connection information.

There is one further issue that should be brought to the attention of the building owner diplomatically: it is not unusual for the structural engineer to determine during the initial probing and documentation phase that additional probes are required to more fully record the building. While one can never fully know the existing layout and condition of a building’s structural system until the actual process of demolition and repair is underway, it is the engineer’s responsibility to delineate and identify as many different elements of structure that occur within a building (especially where they may vary from a “typical” or common configuration). Identifying these variations during the investigation and design phase is often much less costly to the owner, both in time and economic resources, than discovery during the construction phase. This step will permit the engineer to more thoroughly specify the various repairs to be completed.

During the construction phase the presence of the structural engineer on site can be valuable, if not critical, to evaluate conditions that vary from those uncovered during the investigation and design phases. In the case of 101 Spring Street all of the cast-iron cladding was temporarily removed from the exterior of the building. This step permitted the examination of all of the backup structural elements.

**Metallurgical Investigation**

The preparation of construction documents should be accompanied by selective material testing. The most critical of these is metallurgical testing of the existing iron or steel elements.

The laboratory test report from a metallurgical examination should include observations by the metallurgist about the microstructure of the metal (indeed, confirming if the metal in question is cast iron, wrought iron, or an early steel); material properties, including yield strength, tensile strength, and percent elongation during testing; the presence of any deleterious elements that may contaminate or contribute to the poor performance of the cast iron; and potential recommendations about welding electrodes and welding procedures, such as pre-heat or other treatment.

For a number of reasons the welding of new structural-steel members to existing cast-iron members is not recommended where primary structural loads would be transmitted. Localized welding of architectural cast-iron units that have small cracks or missing pieces can be performed, as long as these welds do not transfer or support primary structural loads. Alternate methods to provide structural connections or support potentially include installing redundant structural members or localized reinforcing of existing elements. In select instances it may be possible to install new bolts in old bolt holes or to drill new bolt holes. Installing new holes must be done after careful review of the field conditions by the engineer, the metallurgist, and the contractor who would perform such work.

The structural engineer and the metallurgical testing laboratory must be sure that the metallurgist knows about the proposed uses of the existing material. For example, if there is a desire to weld existing architectural elements made of cast iron, the metallurgist may be able to provide advice about the acceptable pre-heat treatment and welding electrode to accommodate the smaller magnitude forces and the effect such welding might have on the grain structure of the cast iron.

In the case of the Battery Maritime Building, all new fasteners between the cast-iron cladding and the structural-steel frame were made of stainless steel. At 101 Spring Street some new connections, both temporary and permanent, were made by carefully drilling new bolt holes into the cast-iron columns and spandrel panels. No structural welding of primary structural cast-iron members was undertaken in either project.

**Lessons Learned**

The engineer must keep in mind the effect of the proposed structural work on other parts of the project. The structural engineer must coordinate proposed work with the architect’s requirements for window restoration, waterproofing and water drainage requirements, placement of insulation and vapor barriers, and installation of mechanical, electrical, and plumbing systems. On some historic facades the placement or restoration of an exterior fire escape may be required, as was the case with 101 Spring Street.

At the Battery Maritime Building a large collection of original drawings delineated the structural-steel frame that supported the exterior. While there was sheet steel, sheet copper, and stucco on the exterior, the largest portion was clad in cast iron. The construction of the building was well documented with black-and-white photographs, which were most helpful in showing the structural-steel skeleton to which the exterior was attached. This information was invaluable in determining what type of framing was hidden behind the exterior cladding and greatly facilitated the creation of drawings to show the extent of structural repairs.

In the effort to structurally stabilize, reinforce, and repair the Battery Maritime Building, it quickly became apparent that the scope of structural-steel repair was significant and would require coordination with the order and scope of cladding repairs. At 101 Spring Street the potential stability effects of localized loss of materials or connections became a concern early in the investigation phase. In both projects scopes of work were identified in the form of performance documents to help the contractor and the engineer design the temporary shoring and bracing. The performance documents included scope-of-work notes, drawings, and specifications. In other projects it has been helpful to have the contractor’s engineer develop temporary shoring and bracing designs prior to the completion of bidding. With this approach the owner, the architect, the structural engineer of record, the contractor, and the contractor’s engineer are able to review the level of work related to the temporary bracing and shoring, including analysis, design, fabrication, and construction, that is required to maintain the stability of the building. This process has enabled contractors to prepare much more accurate bids for such work.

In nearly all cases existing fasteners were replaced with new stainless-steel bolts, washers, and nuts. New brackets,
angles, and other support materials were fabricated out of new cast iron, mild steel, or stainless steel as conditions warranted. Where corrosion was a primary concern, especially where new members had small overall dimensions, the new structural members were made of stainless steel. In cases where the original bracket had been made of cast iron and the need for its replacement was not due to corrosion of the bracket (perhaps, simply, the unit was missing), new ductile cast iron was used to replace the unit. Where there was little to no concern about future corrosion exposure (for example, in an area where water had never penetrated a facade during the decades of potential exposure to the elements), the design team considered use of mild-steel members with appropriate anti-corrosion coatings.

At 101 Spring Street there were no known original drawings of the building. Careful examination, probing, and measurement of the cladding and the columns and beams provided the only information available about the exterior. The original cladding was reinstalled wherever possible. New cast-iron units were made where units were missing or so severely damaged that they were beyond repair. Only limited permanent reinforcement of the structural frame was required due to the robustness of the original construction. New stainless-steel fasteners, washers, and nuts were used throughout the project to reattach the cladding.

The most valuable lesson learned from both of these projects was the importance of working with a multidisciplinary team that was willing to fully share information and to vet the importance of each major finding from the investigation phase. Bringing the owner’s representatives into the dialogue at the beginning of the probing process provided much greater support of the investigation efforts and the analysis and design work. Ultimately this communication enabled the owners to understand the information as it was discerned and resulted in their support of a more thorough and long-term repair and restoration strategy.

On each building the contractors and the design teams learned from the conditions that were revealed during each phase of the investigation and construction process. For example, once hidden deterioration was uncovered in a certain type of element, the entire team was certain to prioritize and identify repair of similar areas.

Careful attention to the documentation and evaluation of existing cast-iron structural elements and the design of compatible new cast-iron members (along with the introduction of other structural elements) are critical to the long-term durability of cast-iron restoration projects.

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Notes
1. Please refer to the accompanying Bulletin article by Robert Bates for further project details on the recently completed restoration of 101 Spring Street (including discussions on the assessment, repair, and reinstallation of the exterior cast-iron elements).
3. One of the most comprehensive references for cast-iron structural members, including a history of their utilization and design, historic load-capacity formulas, and analysis equations of such members, is Donald Friedman, Historical Building Construction: Design, Materials and Technology (New York: W. W. Norton and Company, 2010).
4. See the Bulletin article by Robert Bates about 101 Spring Street in this issue.