INTEGRATION OF RETROFIT STRUCTURE AND ARCHITECTURE IN AN UNREINFORCED MASONRY BUILDING IN NEW ZEALAND

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ABSTRACT

In earthquake-prone countries, the seismic retrofit of existing buildings constitutes a challenge both technically and architecturally. The first aspect commonly focuses on incorporating new seismic structure to enhance a building’s resistance to earthquake forces. The second aspect corresponds to integrating this seismic structure with the building's existing architecture. Where the former is well understood by designers, the latter remains lightly explored and is rarely carefully considered. Yet, integration of both aspects is particularly relevant as the design of the seismic solution may equally enrich or worsen the architecture of a building.

As part of a PhD research project, a series of recently seismically retrofitted buildings in Wellington, New Zealand, were analyzed. The integration of their seismic systems and existing architecture were reviewed and the designers interviewed. Such a work allowed determining how each retrofit structure impacted on various architectural qualities, as well as how designers justified their design decisions in regard to integration.

The paper dwells on one of these buildings, more specifically presenting the most successful example of integration of seismic retrofit and architecture. The capacity of retrofit structures to contribute to or diminish architectural qualities is thus explored. In addition, the design process is examined in order to understand how the architect and structural engineer integrated the retrofit solution with the existing architecture.

Keywords: Architectural integration; Architectural qualities; Seismic retrofit; Seismic structure

1. INTRODUCTION

Seismic retrofit commonly requires the installation of one or several new structural systems in a building in order to enhance its capacity to withstand earthquakes. The presence of a seismic retrofit structure usually introduces changes to the architecture, therefore questioning their relationship and compatibility. Indeed, several ill-fitting examples of seismic retrofit structure and existing architecture are found in the literature and are also directly observable in many earthquake-prone cities. In many of these buildings, the seismic structure seems simply attached to the façade, often passing in front of windows, or being offset from the axial symmetry, thereby disrupting the architectural elevation. This situation highlights a key issue: in wanting to help a building withstand damage or destruction from earthquakes, seismic retrofit might endanger a building's architecture. This observation raises the following questions: is there a better way to combine both seismic retrofit structure and existing architecture, and how?

This question was the premise for a PhD research project critically exploring the integration of seismic retrofit and architecture, and addressing the different factors and conditions that influence this relationship. As this topic is related to a real-life problem, it was necessary to investigate the current situation of seismic retrofit and understand how integration of seismic retrofit structure and architecture

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was considered and approached by practicing designers. The research thus led to the selection of recently seismically retrofitted buildings used as case studies. The analysis of their degree of integration was undertaken through a combination of on-site visits with direct observations and the interviews of the architects and structural engineers. By understanding which factors reduce integration and which contribute to it, the research aimed to help designers achieve a stronger and more coherent retrofit design regarding seismic retrofit and architecture.

This paper starts by explaining the importance of integration of seismic retrofit and architecture. It then presents a series of architectural qualities which seismic structure has the capacity to influence and therefore to integrate with. In a second part, the results from the review of one building used as a case study are addressed. They are presented from the perspective of the seismic retrofit systems used in the building and their influences on the previously listed qualities. Finally, the outcomes of the designers' interviews are discussed, including the various issues encountered during the design process.

2. INTEGRATION OF SEISMIC RETROFIT AND EXISTING ARCHITECTURE AND PRESENTATION OF THE RELATED ARCHITECTURAL QUALITIES

2.1 Roles of seismic retrofit structure and its relationships with existing architecture

Beyond its technical role, structure has the capacity to interact with architecture. This interaction can be experienced in different ways: from a series of combinations of structural and architectural forms (Macdonald, 2001) to the establishment and expression of architectural qualities (Clark and Pause, 2005). Thus, when approached architecturally, structure can be understood as integrating with a building's architecture. This capacity becomes a valuable asset for designers to convey and enhance their architectural ideas (Charleson, 2014). Structure can be therefore considered as a key component to reinforce and enrich a building's architecture. In this way, structure extends beyond its technical requirements and becomes part of a building's architectural language.

Looked through the perspective of seismic retrofit, the architectural role of structure becomes particularly relevant. As pointed out by Taylor et al. (2002), the engineering purpose of seismic structure, i.e. to resist seismic loads, is only realized during an earthquake. The rest of the time, which represents most of the building's life, the seismic structure becomes an architectural feature, an ornament. This stance highlights the importance of considering the architectural nature of seismic retrofit structure. Moreover, it introduces the potential for retrofit structure to join the architecture of a building and integrate with its existing architectural qualities.

Additional researchers have since reflected on this issue. Practicing engineers such as Cattanach et al. (2008) suggest a 'Transparency' approach in which both the retrofit structure and existing architecture can be read distinctively, with their own unique aesthetics, but with physical and visual compatibilities. The aim is to acknowledge and appreciate the different layers of work that a retrofitted building carries over time. Other researchers challenge common passive conservation approaches when retrofitting a building, in particular, historic buildings. Goodwin et al. (2009), for instance, warn that a rigorous adherence to conservation principles such as the ones set by ICOMOS NZ (2010) do not necessarily lead to a successful retrofit. Instead, the authors exhort designers to be creative and to explore the architectural possibilities that a seismic retrofit solution may provide. Similar encouragement is made by McClean (2010) who refers to the Earthquake Architecture movement which aims at expressing an architectural language stimulated by the seismic risk. This reference aims primarily at supporting the idea of an architectural contribution by the seismic retrofit. His purpose is to stimulate architects and structural engineers in proposing seismic schemes that simultaneously respect the existing heritage fabric of a building while enhancing its architectural qualities.

Charleson and Southcombe (2017) further discuss the idea of enhancement of existing architectural qualities by seismic retrofit. In the 'Dialogue' approach, the seismic retrofit solution is used as an opportunity to reflect on a building's existing flaws and qualities in order to improve them. Several strategies can be used, such as partially hiding or exposing the seismic structure, juxtaposing or
interweaving it with the existing architectural layers. This approach aims at being more critical of the existing architectural qualities of a building in comparison to the other approaches identified by the authors; namely 'Indifference', 'Invisibility', and 'Separation'. 'Indifference' corresponds to the treatment of the seismic solution as solely an engineering problem. No architectural reflection is undertaken, leading to the risk of structure negatively impacting on existing architecture. The second approach corresponds to the hiddenness of the seismic solution as recommended by conservation principles and commonly accepted by designers. The third approach is similar to the concept of 'Transparency' defined by Cattanach and previously mentioned. All these different relationships suggest that the addition of retrofit structure to an existing building can have different impacts and influences on existing architectural qualities.

2.2 List of architectural qualities relevant to seismic retrofit

An identification of architectural qualities that seismic retrofit structure can integrate with was established based on the review and analysis of two types of sources. The first type addresses the most common contributions of structure to architectural qualities as discussed by researchers including Von Meiss (1990), Macdonald (2001), and Charleson (2014). The second type of sources relates to the characteristics and challenges associated with the seismic retrofit context, in particular the conservation preservation principles recommended by Look et al. (1997), Robinson and Bowman (2000), and ICOMOS NZ (2010). The result is a total of 16 architectural qualities divided into seven categories:

- **Category 1: Hidden seismic retrofit structure.**
  It focuses on the architectural reasons justifying the hiddenness of the retrofit structure and the selection of the concealment technique.

- **Category 2: Exposed exterior retrofit structure.**
  It considers the elevation of the building's façades, and the expressiveness of the structure.

- **Category 3: Exposed interior retrofit structure.**
  It relates to the same architectural qualities than the ones mentioned in Category 2, yet internally. Interior qualities such as space, function, and circulation are also introduced.

- **Category 4: Existing external openings.**
  It considers the modulation of natural light and any impact on outside views the structure may have.

- **Category 5: Ornament.**
  It addresses the capacity of the retrofit structure to serve ornamental purposes.

- **Category 6: Architectural concept.**
  It focuses on the capacity of seismic retrofit structure to contribute to the expression of an architectural concept whether new or already expressed by the existing building.

- **Category 7: Key conservation and preservation principles.**
  These include minimum intervention, compatibility with the building's existing architectural character, and reversibility of the seismic work.

As part of the PhD research, this list of categories and their architectural qualities was developed into a checklist. Using a series of questions related to each quality, a reviewer can determine the impact and influence the seismic retrofit structure has on each quality. The checklist was used to assess the level of integration of seismic retrofit and architecture for each of the buildings used as case studies including the following case study.
3. ANALYSIS OF THE INTEGRATION OF THE SEISMIC RETROFIT SYSTEMS IN THE SELECTED URM BUILDING

3.1 General description of the building

The selected case study is a 4-storey building built in 1908 to which an extension was added at its rear in 1985. It is composed of solid unreinforced masonry walls (URM) in its longitudinal direction, as well as steel beams and cast iron columns supporting timber floors. The building is listed as a Historic Place Category 2 mainly due to its Edwardian Baroque front façade. The seismic retrofit solution was achieved in 2013 and reached a 100% of the New Building Standard (NBS). The retrofit consists of shotcreted concrete to the URM walls, two major reinforced concrete moment frames in the transverse direction (Figure 1), and new composite steel deck and concrete-filled diaphragms at each floor (Figure 2). In addition, the concrete framed extension is separated from the existing building in order to avoid torsion and the cast iron columns are removed due to their brittleness and inability to perform well during an earthquake. The seismic retrofit was undertaken conjointly with an internal refurbishment. The ground and first floors are used as a retail store and the upper floors as offices.

3.2 Integration of the seismic retrofit solution and the existing architecture

The data obtained from the on-site review of the integration of the seismic retrofit solution and existing architecture are communicated through a series of Tables of Analysis. Each of the tables displays the characteristics of the seismic system being analyzed and the architectural qualities potentially impacted. The use of a color code allows quick appreciation of the influence of the seismic system on each architectural quality (Figure 3).
Table 1 combines three Tables of Analysis which show the contribution of the seismic retrofit design to the building’s architecture. Overall, all architectural qualities have been enhanced at least once with the exception of three sub-categories: 4.1 (Modulation of light), 4.2 (Outside views/sightlines) and 7.3 (Reversibility).

Table 1. Tables of Analysis representing the influences of the seismic systems on architectural qualities

3.3 Integration of each seismic retrofit system and existing architectural qualities

The analysis of each quality allows an understanding of the reasons justifying the influences of the seismic systems and how some of these influences contribute to successful integration.

- Shear walls

In Category 3, the shear walls contribute positively to both the interior elevation (3.1) and expressiveness (3.2) qualities. This is first due to the interior refurbishment undertaken alongside the seismic retrofit which resulted in the removal of previous fit-outs. As a result, new long and continuous elevations with raw concrete materiality are displayed. In addition, the roughened surfaces express technical aspects of their construction, more specifically the sprayed concrete process known as shotcrete. Combined together, the elevations and their detailing contribute to an industrial character.
The location of the shear walls is the main reason justifying their neutral integration with architectural qualities such as space (3.3), function (3.4), circulation (3.5), natural light (4.1), and outside views (4.2). As the new structure is placed against the existing perimeter URM walls, the delineations of the internal spaces are maintained. No further openness or enclosure, whether visual or physical, is provided by the new retrofit structure. Their location also ensures that openings and views are not impacted by the presence of the shear walls. In addition, any modulation of natural light is non-existent as the exposed concrete walls and their roughened surfaces avoid any reflection.

Due to the lack of ornamental features of the existing walls, the presence of the new retrofit shear walls does not result in any loss or damage of any existing ornamental quality (5.1). The capacity of the shear walls themselves to be considered as ornament is however limited for two main reasons. Firstly, they share an exposed concrete materiality with the transverse retrofit structure, i.e. massive moment frames, and new composite floors (Figure 4). Such an omnipresence of exposed concrete materiality reduces the potential for the shear walls to appear as ornamental objects. Secondly, the shear walls are visually affected by new columns and moment frames that prevent their appearance of linearity. In addition, these discontinuities do not generate any pattern or rhythm on the walls.

![Figure 4. Third floor with exposed seismic retrofit systems, including concrete shear walls, concrete moment frames, and composite decking with a concrete surface on the floor and a steel surface at the ceiling. Steel plates from previous strengthening work are visible on the interior side of the front façade (Source: https://nz.hougarden.com)](image)

Taking the advantage of a full internal refurbishment, the new seismic solution generates a new concept (6.1). The shotcrete shear walls show their raw concrete materiality and detailing. Their large dimensions, covering the full height of each floor and the entire length of the building also reinforce their presence. With these characteristics, a contrasting concept emerges based on the distinct reading of the existing refined Edwardian Baroque front façade, and the raw industrial character of the shear walls. In addition, the new moment frames and composite steel and concrete floors also express raw concrete materiality and detailing. This similarity between the shear walls and these structures ensures coherency between them and reinforces the expression of a design concept (Figure 5).

The building is listed as heritage, therefore requiring particular care in regard to conservation principles (Category 7). The seismic solution positively complies with minimum intervention (7.1). Indeed, the shear walls are installed internally therefore avoiding any contact with the exterior surface of the front façade carrying the key architectural and historic features. In addition, the raw exposed shear walls bring a new architectural character that contrasts with the existing character expressed by the façade without disturbing it. A sense of surprise is created. Such a design enhances compatibility with existing architectural character (7.2). The shear walls can be considered as being removable (7.3) without affecting key architectural features. However, due to their size and location, their removal combined with the repair of the URM walls behind them would represent a massive undertaking.
Moment frames

The moment frames largely enhance the architectural qualities in Category 3 with the exception of the interior elevation quality (3.1) which remains neutral. This is due to the significant distance between the retrofit structure and the rear and front façades resulting in a lack of relationship with them. Also, the disposition and the small number of moment frames barely enliven the longitudinal surfaces of the new shear walls. No rhythmical composition or ornamental features are developed.

The two moment frames are aligned on an existing grid of load bearing cast-iron columns which have been removed during the retrofit. Despite being based on an existing grid, the moment frames manage to enhance several architectural qualities. This is primarily due to two characteristics: the reduction of the number of columns and the larger dimensions of retrofit structure. The result is an emphasized expressiveness of the structure and entrance (3.2), combined with a greater spatial openness (3.3) and a new definition of internal functions (3.4). The middle bay of the two moment frames also delineates a new horizontal opening combined with escalators connecting the ground and first floors (Figure 6). The retrofit structure thus helps distinguish the vertical circulation area from the usable spaces located to the sides and facilitates users understanding of how the ground and first floor operate (3.5).

The retrofit structure is installed far enough from the façade to avoid any impact on the entry of natural light. In addition, the three bays of the two moment frames are aligned with the columns of the façade, further limiting light obstruction (4.1). The location and geometry of the retrofit structure also maintain the existing views toward the outside (4.2). The integration of moment frames and the architectural qualities of Category 4 can therefore be considered as neutral. Similar integration can be noticed regarding ornamental quality (5.1), as the omnipresence of exposed concrete throughout the building.
weakens the reading of the moment frames as unique ornamental features. This same omnipresence however allows the moment frames to contribute to the architectural concept quality (6.1) due to their massive dimensions and raw detailing.

The minimum intervention (7.1) principle is considered positively achieved by the moment frames as their interior location avoids any changes to the architectural and historic features of the front façade. Similar comment can be made regarding compatibility with existing architectural character (7.2). In addition, the moment frames contribute a new architectural layer. They express an industrial character, working in contrast with the façade. Concerning reversibility (7.3), the exposed moment frames are deeply connected to several structural elements. The most critical connections are at the junction with the longitudinal URM walls. In order to accommodate the installation of the new columns inside the existing structure large cuts were made. The removal of the retrofit structure would then require careful repair and restoration of the existing URM walls. Integration of the retrofit structure and reversibility is therefore considered as neutral.

- Diaphragms

As horizontal systems, the diaphragms have barely any physical interactions with the interior spaces, limiting their potential contributions to visual architectural qualities. Yet, this limitation does not prevent the horizontal retrofit structure from positively integrating in various ways with the architecture. The internal refurbishment led to the replacement of the original timber floors by new composite steel and concrete decking. As a result, the diaphragms display two surfaces (3.1). The top surface is continuous raw concrete similar to the shear walls. Its bottom surface is composed of a longitudinally-oriented trapezoidal profiled decking supported by transverse universal beams (UB). In the case of the ground and first floors, the UBs are supported by two pairs of castellated beams located along the edges of the large horizontal opening in both floors. The detailing of the composite steel and concrete decking also fully expresses its materiality and construction technique (3.2) (Figure 4).

The new composite floors make two contributions to circulation quality (3.5). First, the two pairs of castellated beams run in the longitudinal direction and connect the central bays of the front and rear moment frames. Their strong presence signals the direction of movement and suggests users move from the entrance to the rear end of the building. Secondly, the castellated beams delineate the longitudinal boundaries of the central horizontal opening. In so doing, the horizontal structural components contribute to the identification of vertical circulation. The castellated beams also possess a unique pattern of hexagonal holes which makes them stand-out from the rest of the horizontal structural components and justifies their identification as ornament (5.1) (Figure 7).

The technical detailing and raw materialities of the composite decking further supports the shear walls and moment frames in the expression of the architectural concept (6.1). A similar argument can be made regarding compatibility with the existing architectural character (7.2), resulting in a positive contribution

Figure 7. Middle bay of the moment frame framing the vertical circulation area
of the composite floors to this quality.

Unlike the vertical retrofit structures, the new composite floors are considered to neutrally integrate with the minimum intervention quality (7.1). This is due to the uncertain value of the existing wooden floors replaced by the new diaphragms. As a result, a moderate loss of architectural features can be assumed.

The new composite floors utilize two main types of connections. The most straightforward ones to remove in the event of future refurbishment are the bolted connections between the different steel components. More challenging are the dowelled connections between the steel beams and the concrete shear walls, URM walls, and moment frames. Their removal would lead to damage of the concrete and URM walls and would involve repairs. Also, all the services attached to the composite floors would require removal and reinstallation. With no meticulous and deep thought about the reversibility (7.3) of the composite floors, the integration of the diaphragms regarding this quality is considered neutral.

4. DESIGNERS' VIEWS ON INTEGRATION

4.1 Consideration of the architectural qualities

The architect and structural engineer in charge of the project were interviewed regarding their consideration of the integration of the seismic retrofit and architectural qualities. Their responses allowed identifying several reasons explaining the successful integration of their retrofit design.

First, a shared and clear vision drove the seismic retrofit design. The respondents agreed on a concept and on the role the seismic structures would take in it, thus legitimizing their presence from an architectural perspective. The fact that both designers were aware of the double role of the structures, as both technical and architectural components, gives an initial explanation for the overall positive influence of the seismic retrofit on architectural qualities. Although agreeing on a concept, not all architectural contributions of seismic structure were fully planned. Where some were sought by the designers, others were fortuitous. The castellated beams were an example of a structural necessity turned into an architectural asset.

The difference of architectural and historic importance between the various existing parts of the building was a factor influencing integration as it provided both additional freedom but also constraint. The existing façade, the key component of the building, limited any contribution of seismic structure to architectural qualities such as modulation of natural light and outside views. In contrast, the existing cast-iron columns and timber floors were not considered as carrying much value. Their removal allowed for architectural qualities such as space and circulation to be improved.

The requirements of two stakeholders were mentioned as influencing the integration issue. They responded to the initial demands of the tenant and the building owner. These demands, such as connecting the ground and first floors and maximizing the interior space, set broad parameters that oriented the design and to some extent influenced the respect of the existing architecture. The designers however remained in charge of accommodating the design with the programme. They could therefore discuss the requirements early in the design process if these appeared harmful to the building. They could also consider the potential of the programme to enhance the architecture.

The architect approached the integration issue with both the present and future in mind. Function and ornamentation qualities were thus considered in such a way that the incorporation of future new programmes could be facilitated. The usability of the building throughout its life span appeared therefore as another architectural consideration driving the retrofit solution. This approach to the seismic solution enhanced functionality. Regarding ornamentation, the neutral influence of shear walls and moment frames was explained by this expectation of future accommodation, as well as by a desire to introduce a contrasting concept between interior and exterior characters. An ornamented treatment of the seismic components would have been contrary to the architectural concept, and would have weakened it. This means that any lack of contribution of structure to an architectural quality should be put in perspective.
with the overall treatment of the building.

The last aspect mentioned was the consensus of the owner and architect on the legitimacy of the structure to remain inside the building and become inseparable from it and from its architecture. The architectural contribution of the seismic retrofit was considered so important that the architect predicted it will become part of the historic value of the building in the future. This attitude raised an interesting thought regarding the reversibility principle. As the Tables of Analysis reveal, the seismic structures have contributed to the enhancement of many architectural qualities. This implies that their removal would affect these qualities. Aspects such as architectural character or concept might be drastically weakened or lost. Based on this argument, the attitude of the owner and architect to not consider the reversibility of the seismic retrofit structures becomes justified. This also suggests that the design of future seismic structures, in the place of or in combination with previous seismic solutions, should respect not only the original architectural qualities but also those of previous retrofits.

4.2 Time of involvement of the stakeholders

As presented in Table 2, the project started with the client engaging the structural engineer in order to check the earthquake-prone status of the building and target the seismic retrofit to 100% NBS. At the Concept Design stage, two additional stakeholders got introduced to the project; namely, the architect and the main tenant.

The architect and structural engineer indicated that the Concept Design was the key stage in the design process. Their combined presence at that stage was a key factor in the success of the integration of the seismic retrofit and existing architecture. The engineer explained that this allowed the architect to be involved in the choice of the structural system and point out the architectural parameters considered of importance. This also ensured that the main tenant's needs were taken into account, meaning that the fundamentals of the retailing requirements were understood and considered. As stated by the architect, the retrofit design became integrated "when it felt like we got a scheme that worked structurally, architecturally but also commercially". The dialogue between the designers at such an early stage avoided future issues as the risk of major changes later during the design process was prevented. The architect also mentioned Detailed Design as the second most important stage. Both designers contributed to it. Constant dialogue and clear communication between them was therefore vital. It was during this stage that the simple and raw aesthetic of the retrofit solution became clearly defined and was designed. As pointed out in the previous section, this aspect was paramount to the successful expression of the concept. The roles and contributions of some stakeholders, especially the contractor during the construction phase, were mentioned by the engineer. The contractor suggested technical details that led to a better achievement of the intended concept. Other stakeholders such as the City Council and Heritage NZ had more minor roles. The first solely checked the proposed seismic retrofit design and had no influence on it. The second had no direct involvement in the design and was only referred to
during the Concept Design stage in order to review heritage principles.

4.3 Leadership

The project started from the intention of the owner to seismically strengthen the building in order to encourage new tenants. The project was thus mainly approached as structural work which led the structural engineer to assume the role of project leader. With a strong experience in seismic projects, the engineer provided leadership throughout the entire process. She ensured that everything proposed was "feasible and viable" which involved meeting with the different stakeholders when necessary and considering their suggestions. In one case, the contractor even hired the engineer as structural advisor as some works were particularly complex and integral to the new seismic design. The stakeholders could therefore rely on the structural engineer at any step of the design process and construction phase.

While leading the project, the engineer praised the contribution of the architect during the design process. His experience, as well as their pre-existing relationship on previous projects, contributed to a solid partnership during the retrofit design. They discussed ideas during several meetings throughout the design process. This avoided any competition between them and ensured that they were aiming toward a same goal. These meetings allowed them to ask questions on specific issues rather than making assumptions, clarifying points of view, explaining and justifying design decisions, and reflecting together on design alternatives when necessary.

4.4 Issues and constraints during the design process

The designers acknowledged that several constraints drove the retrofit design. The influences of these constraints on the seismic solution and its integration with architecture varied. A first factor was the heritage value of the building. This was mainly characterized by minimizing disruption to the façade. This constraint restricted the seismic solution to the interior of the building. The second factor resulted from the tenant's requirement to keep interior spaces as open as possible. This request prevented the use of cross-bracing as initially considered, and led to moment frames with large cross-section dimensions. The third constraint was the site. Due to limited access, many structural components had to be built directly inside the building. For instance, the moment frames and their detailing resulted from the cast-in-place process. Another constraint was the temporary support required while dismantling part of the building and constructing the new structural components simultaneously. As explained by the architect, such an approach forced the new moment frames to be installed in front of the existing cast-iron columns and thus ending up slightly off grid. Comparing these four constraints with the Tables of Analysis reveals that, while these constraints influenced some design decisions, they have not weakened any architectural quality. The designers also acknowledged the timeframe and budget as two additional considerations. The short schedule was difficult to achieve, but the budget was not as constraining. None of the designers however mentioned any direct influence of these two aspects on the seismic design. Instead these considerations were presented as aspects that were present but did not change or weaken the designs.

5. CONCLUSIONS

The paper highlights the importance of integration of seismic retrofit and architecture, and widening the perception of retrofit structure. The installation of new seismic systems is considered beyond their simple impact on existing architecture, and instead, as an opportunity for designers to contribute to the architectural qualities of a building.

The case study stresses the careful reflection undertaken by the practicing designers in understanding the architectural role of their retrofit solution and developing it through a shared concept. The analysis of the retrofit shows how vertical and horizontal structures, through their location, materiality, detailing, geometry, and scale, integrate with different architectural qualities. Some seismic systems appear more predisposed than others to enhance specific qualities. This is the case with the moment frames and qualities such as space, function, and circulation, in comparison to the neutral integration of the shear
walls. These observations are however specific to one building. Other case studies analyzed in the PhD research display more varied results.

The designers' reflections on their retrofit design highlight factors determining the overall success of integration. The first factor was the timing of involvement of the architect at the beginning of the Concept Design stage and his increased contribution during the Detailed Design stage. His presence throughout the design stages provided architectural input on the structural design and allowed the architectural concept to be realized in the detailing. The second factor was the role of the structural engineer as the leader of the design team. She was accessible to any stakeholder, provided guidance, encouraged dialogue through meetings, and even took on additional tasks when her expertise was needed. Finally, heritage preservation, interior openness, and site constraints have influenced the final design. However, they were considered less as restrictions impacting decisions, but more as legitimate requirements providing opportunities for greater considerations. They forced the designers to think about ways to incorporate them in the design while being relevant to the architectural concept.

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7. REFERENCES


