The relationship between seismic retrofitting and architectural qualities

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ABSTRACT: Any building to be retrofitted possesses its own existing architectural quality that structural engineers and architects have to address when seismic strengthening is considered. Both professionals rely on their experience in order to reach a solution providing the right balance between seismic strengthening and preserving existing architectural features. Currently no evaluation system offers a means to understand or to reflect on the impact of seismic retrofitting on the existing architectural qualities of a building.

This paper discusses issues that arise when seismically retrofitting existing buildings, from an architectural point of view. It also describes an evaluation system under development to assess the impact of seismic retrofitting on existing architectural qualities. The aim is to help designers critique their designs by considering the architectural consequences of proposed seismic solutions early on in the design phase. Implementation of this evaluation is also intended to enhance the dialogue between different stakeholders of the project by providing a common basis of information and assessment vocabulary.

1 INTRODUCTION

In earthquake-prone countries, the issue of retrofitting existing buildings not meeting seismic standards has been, over the years, a major challenge for designers. During the last decades, there have been great improvements in terms of technical solutions, design methodology and legislative means to help retrofit designs be adapted better to the expectations of designers and clients (Dhakal 2011; FEMA 2006b). These enhancements have led to more effective solutions in terms of seismic behaviour and cost. Yet, it appears that the integration of the retrofit solutions with the architecture of existing buildings remains a frequently overlooked issue that needs to be considered more deeply by stakeholders.

The understanding and acknowledgement that architecture is an integral component of seismic retrofitting design allows existing buildings to be retrofitted to achieve *both* effective earthquake resistance and enhanced architecture quality. Some publications stress the importance of architecture by providing designers a series of guidelines for them to follow during the retrofit design process. However, these guidelines and their recommendations, despite helping architects and structural engineers become more aware of existing architectural features, do not specifically emphasis the impact of seismic retrofitting on the architectural qualities of an existing building. Whether a proposed design leads to an existing architecture being positively or negatively affected by the presence of seismic retrofit components is not addressed by current publications.

This paper highlights the current relationship between architecture and seismic retrofitting, as well as revealing the issues arising from this situation. It also proposes an evaluation system, currently under development, assessing the impact of seismic retrofitting on existing architectural qualities. Its aim is to improve the consideration of the architecture of any existing building when planning seismic retrofitting. By being more aware of the consequences of their design decisions, designers and clients should then be able to provide retrofitted buildings with enhanced overall architectural quality.

2 ARCHITECTURAL ISSUES IN SEISMIC RETROFITTING

2.1 Architectural considerations in non-heritage buildings

When planning to retrofit an earthquake-prone building a series of initial considerations, whether imposed on the design team or based on the stakeholders' concerns, influence the design of any seismic proposition. The American Society of Civil Engineers (2007) identifies these considerations, as: "*structural characteristics*", "*site seismic hazards*", "*results from prior seismic evaluations*", "*occupancy*", "*historic status*", "*economic considerations*", "*societal issues*" and "*local jurisdictional requirements*". Once a potential seismic scheme is generated it appears that another series of considerations are used to evaluate it. The Federal Emergency Management Agency (2006a, 2006b) indicates that the appreciation and selection of a seismic solution is essentially based on the building owner's or user's concerns which can be identified as: "*seismic performance, construction cost, disruption to the building users during construction (often translating to a cost), long-term affect on building space planning, and aesthetics, including consideration of historic preservation"*. As the seismic retrofitting of an earthquake-prone building will almost always imply visual modification, it is surprising to not find 'architecture' per se as one of the considerations listed above. It is instead covered in a very limited way in the "*building space planning*" and "*aesthetics*" sections which FEMA states are not deeply considered. "*Building space planning*" is regularly thought of as lesser importance than other considerations and is usually sacrificed in favour of the latter. "*Aesthetics*", despite being usually agreed upon as a criterion for judging a retrofit solution, is also often sacrificed in the interest of cost and disruption to building use when retrofitting non-heritage buildings. It thus appears that the different criteria considered by the designers and clients do not have the same level of importance, especially architectural ones, as compared to others such as seismic performance or cost (Charleson 2008; FEMA 2006a, 2006b).

When referring to literature on seismic retrofitting, it appears at first sight that architecture is being taken into account in a more respectful way. Indeed, several documents helping architects and engineers to develop seismic retrofit solutions with reference to architecture do exist. These documents either aim at 'teaching' designers, and particularly architects, to better understand seismic engineering issues (Charleson 2008; FEMA 2006a) or at providing more technical and structural information for engineers (ASCE 2007; FEMA 2006b). In both kinds of sources, architectural issues are treated in two different ways: the first focuses on how architectural components might affect the behaviour of the seismic responding structure, while the second concentrates on the repercussions of seismic retrofitting on architectural characteristics. However, the latter tends to be of lesser concern, particularly when a building to be retrofitted is not listed as heritage. It thus appears that design team members might rely more on their personal knowledge and experience when considering the effects of retrofitting on architecture, than on written documents.

2.2 Architectural considerations in heritage buildings

Conversely, architectural integrity and architectural appearance are considered highly important when retrofitting heritage buildings as they emphasis their cultural heritage value (ICOMOS NZ 2010). Any modifications to these particular buildings have to be based on the conservation and preservation of heritage values. Therefore, a consequent number of international and national documents, mostly guidelines, help designers of these particular buildings to undertake modifications, and consequently seismic retrofitting. The documents aim at limiting or at least helping to control the changes that may occur within these buildings (CBSC 2013; Goodwin et al. 2009, 2011; ICOMOS NZ 2010; Look et al. 1997; Nelson 1988 ; NZHPT 2007).

Two categories of recommendations provided by the different guideline documents can be identified. The first helps designers to determine the different architectural features prior to any retrofitting scheme. Its aim is to make designers aware of the existing visual features (fabric, ornaments, spaces, etc.) that constitute the architectural character of the building. Most of these documents provide limited assistance in the identification process. They simply specify a list of features to look at, and only focus on purely visual architectural aspects. More intangible components, such as functionality or quality of natural light for instance, are not taken into account. The second category provides guidance during the design process and construction phase. This guidance comes in three formats: statements to consider, questions for designers to answer, and checklists. Each of these formats intends to help the designers providing a seismic retrofit by preserving and conserving existing architectural characteristics. Despite this assistance, they possess limited assessment on the consequences of the seismic retrofitting on the existing architecture. In conclusion, the way the new seismic components might influence an existing architecture by improving its qualities, or by reducing them, is not addressed by current publications.

2.3 Impact of seismic retrofitting on architectural quality

Seismic retrofitting approaches include a wide range of techniques and each implies an impact on the architecture with a unique series of consequences on various architectural qualities (ASCE 2007; Charleson 2008; FEMA 2006b; Goodwin et al. 2011; Nishizawa 2008). It is the designers' task to not only consider such an impact, but to ensure its good relationship with the different components defining the building's overall architectural quality. The combination of several techniques within the same seismic retrofitting can also accentuate the presence of the seismic components and thus the consequences on the architectural qualities (Cattanach et al. 2008; Nishizawa 2008). The outcomes of the impact can be appreciated differently from one designer to another. Indeed, each professional, based on his or her experience, can consider a seismic retrofitting proposition as either positive, when the existing architectural qualities are improved; neutral when no changes are perceivable; or negative when the architectural features are badly affected (Figure 1).

Figure 1. Inadequate braced frames not matching the arches of the existing façade (left). Poor integration of a braced retrofit structure (right).

Any retrofitting technique can comprise either of two approaches to their expression: hidden or exposed (Figure 2). In the first case, the visual presence of the seismic retrofitting is not desired and thus designers strive to hide it. The main reason justifying this approach is the preservation of the building's original architectural and historical character (Goodwin et al. 2009, 2011; Look et al. 1997). The second option expresses the retrofitting solution. Several reasons can justify this approach: to clearly distinguish the original architecture from the new seismic structure (Goodwin et al. 2009); the retrofitting scheme is designed with an architectural concept of highlighting the seismic issue (Charleson 2008; Slak & Kilar 2008); and the attitude that the seismic structural components and non-structural elements, through their intrinsic characteristics, layout, dimensions and shape, can enhance the existing architectural character (Goodwin et al. 2009).

Figure 2. Shear walls hidden inside the building, keep the existing façade untouched (left). Braced frames exposed on the façade of the building (right).

Seismic retrofitting gives the opportunity for components external to the existing building to provide additional architectural characteristics to the building. According to Taylor et al. (2002) seismic resistant structure acts as mere ornament when not confronted by an earthquake. This statement implies that during most of its lifetime this structure can potentially provide additional aesthetic qualities to the existing building. Seismically retrofitting an existing building can also lead to the introduction of another range of qualities and characteristics such as new fabric, added insulation, restoration of lost features, etc. Yet, the most significant outcome might be the addition of a whole new extension to a building. This is the case at the International Library of Children's Literature in Tokyo (National Diet Library 2006). The seismic retrofitting project includes a range of new components and spaces such as a new entrance, bathrooms, cafeteria, lounge, and vertical and horizontal circulation. As a result, the appearance of the north-west façade has been completely modified (Figure 3). These examples stress the fact that designers and clients should not only consider the impact of seismic retrofitting on the existing architectural characteristics of a building, but also on the potentially new added ones.

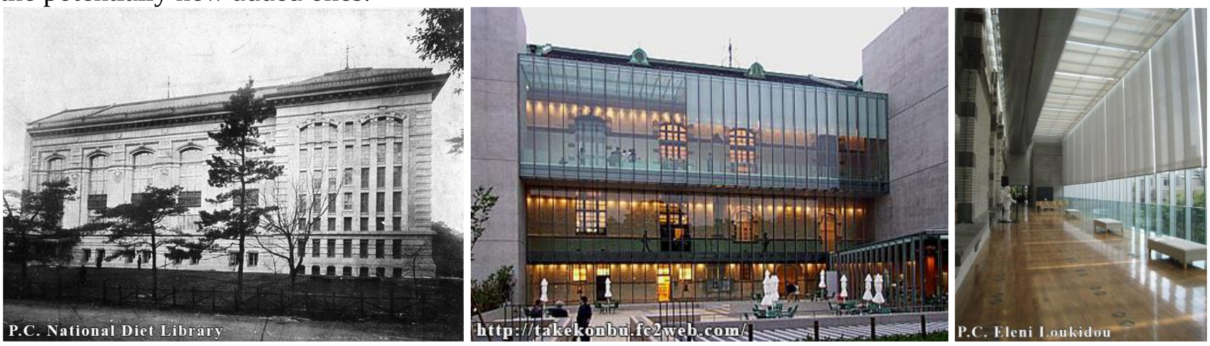

Figure 3. Pre-retrofitting south-east façade (left). New glazed north-west façade (centre). The distance between the former and new north-west façade has been developed as a circulation space (right).

Analysing the impact of seismic retrofitting on the final architectural quality of the retrofitted building is an important task that should be undertaken both by the architect and structural engineer on buildings of architectural significance, whether heritage or non-heritage (Cattanach et al. 2008; Goodwin et al. 2009). However, the impact of seismic retrofitting upon architecture is extremely variable due to the multiple factors involved: retrofitting techniques, constraints of the existing building, cost, stakeholders' considerations, etc. Guidelines and pre-established principles cannot determine every retrofitting scenario and constraint that occur in live projects. It is therefore necessary to develop a more adaptable and relevant approach.

3 SEISMIC RETROFITTING EVALUATION SYSTEM

The first part of this paper reveals the lack of an effective system helping designers to analyse and assess the impact a seismic retrofitting solution on the architecture of an existing building. The risk is for professionals to unintentionally affect architectural elements in a careless way, or at least not to consider the full repercussions of their proposition(s). Furthermore, the absence of attention to the architectural issue will enhance the client's decision-making toward cost and technical concerns.

A new approach is needed in order to provide a resolution to the current situation. First, architectural considerations need to be raised to a higher level of concern in order to be acknowledged by the designers and the clients when reviewing a seismic retrofitting scheme or comparing several propositions. Secondly, reflection on the consequences of the integration of seismic components on architecture should be encouraged. Thirdly, an effective assessment of the impact of seismic retrofitting should imply a degree of flexibility. Indeed, due to the different factors influencing the seismic design of an existing building, an 'infinite' combination of propositions is possible and each of them implies a unique series of architectural consequences. Furthermore, the expectations of the stakeholders might be different from one building to another especially between non-heritage buildings and heritage ones. Finally, as such an assessment should be usable on any seismic retrofitting project, an evaluation framework effective on a large range of buildings is necessary.

3.1 Architecture design competition evaluation process

Architectural design competitions are widely accepted by professionals and lay people as an effective procedure to evaluate the architectural quality of any project. A logical approach is then to undertake the development of an evaluation system assessing the impact of seismic retrofitting on architecture drawing upon these types of competitions, and especially their assessment processes.

The evaluation of project entries is based on a series of steps that are specific to each competition: individual/collective analysis, debate, ranking, etc. However, one common approach is the use of widely agreed assessment criteria helping the jury members to form their respective opinions on any architecture propositions (AIA 2010; Kazemian & Rönn 2009). Rönn (2011) indicates that each of these criteria implies a series of questions that evaluators refer to in order to build up their respective opinions. Such approach allows to assess the architectural quality of competitions entries, as the combination of architectural criteria and questions generates an evaluation framework usable on types of buildings (Figure 4). This framework not only allows any evaluator, whether professional or not, to undertake a personal reflection on the architecture of any building but also to share it with others using a same basis for dialogue. The outcome of such an approach leads to a decision based on a common agreement between different evaluators.

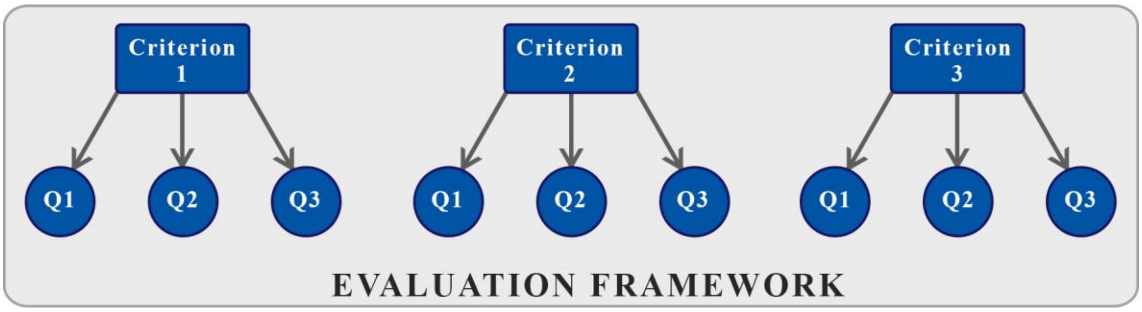

Figure 4. The combination of the different criteria and of their respective questions generate a specific evaluation framework.

The aim of the evaluation system to be developed is slightly different from architectural competitions as the former intends to assess the impact of seismic retrofitting on architectural qualities whereas the latter evaluates these qualities. Despite this difference, an evaluation framework similar to the ones generated by architectural competitions appears to be a relevant component for the proposed evaluation system.

3.2 Evaluation systems related to seismic retrofitting impact

Some structural engineers have already started to reflect on the impact that seismic retrofitting has on the architectural qualities of a building, yet with limited consideration.

Nishizawa (2008) presents a table evaluating a series of seismic solutions against six criteria. Out of these six criteria, only two are related to architecture. The first criterion focuses on the impact of the seismic work on the building's operations. The second refers to the impact of the retrofitting on the cultural asset. Two sub-criteria arise from this last consideration: the "*Changes to the exterior of the building*" and the "*Degree of effects on the registered cultural asset*". Although the mentioned criteria and sub-criteria are related to architectural concerns, they remain very basic and limited. They are actually far from helping designers/evaluators to effectively analyse the consequences of their seismic schemes on architectural qualities. In terms of usability, Nishizawa's evaluation and comparison table is based on a combination of written observations and scores. The former describe how the criteria and sub-criteria are affected by each solution; the latter are assigned to each criterion. Despite its relevance, this approach is too simplistic and could be improved by using critical reviews instead of 'objective' observations and scores not only related to the main criteria but also to the sub-criteria. Nishizawa's evaluation table aims at facilitating decision making but tends to result in an over-simplified evaluation outcome.

Cattanach et al. (2008) propose an "*appraisal framework*" quite similar to the Nishizawa's evaluation and comparison table. The most noticeable differences are the use of additional architectural criteria and the absence of a score attributed to each criterion. Despite greater consideration to the architectural qualities of a building, the appraisal framework remains limited. First, the architectural parameters are very general and need be further developed and detailed, leading eventually to sub-criteria. Secondly, additional criteria should be added such as natural light, insulation, acoustics, adaptability (Gann et al. 2003), level of symbolism (Slak & Kilar 2008; Taylor et al. 2002), expression/concept (Slak & Kilar 2008).

Both Nishizawa and Cattanach have begun to consider the impact of seismic retrofitting on architectural quality. However, this area of research remains lightly explored by structural engineers and architects. Two primary issues have yet to be examined in order to properly assess and compare the impacts of seismic retrofitting on architectural quality:

- provision of a sufficient number of criteria and sub-criteria to be evaluated, to reduce the risk of the designers/evaluators unintentionally missing important architectural issues.
- develop an effective evaluative and comparative system. Without being too simplistic, it should allow the client to easily examine a seismic proposal and compare it with others. The outcome of such an assessment should help decision making without imposing any seismic scheme on the client.

3.3 **Additional aspects to consider**

As the evaluation system assesses the impact of seismic retrofitting on architecture, both the architect and engineer are intended to be evaluators. Depending on the situation, it may be that only one of them undertakes the assessment. This implies that the architectural criteria and their related questions should be understandable by both professionals (and also by the client). In this regard, the generated framework will be similar to those of architecture competitions in which any of the jurors can review the strengths and weaknesses of any project entry.

In order for the evaluation system to be relevant and useful for both designers and clients, it should be used at an early stage in the design process. The architectural criteria and associated questions need to be adapted to the level of detail and information available at this stage in the design. Once the structural engineer has designed one or more seismic retrofitting schemes the evaluation should be undertaken and the outcomes presented to the client. The client will then know early on how the existing architecture of the building will be affected, if the proposition reaches his or her expectations and if not, whether it can be modified. Such an early evaluation is preferable to a later one as it reduces the risk of future alterations and additional costs.

Apart from the architectural criteria and questions, several other key aspects have also to be considered: the evaluation process and the representation of the evaluation results. Concerning the first aspect, the evaluation system is meant to assess a single seismic schemes but it might also compare several propositions if needed. The combination of written observation and scores, as used by Nishizawa, appears a relevant approach for both scenarios. Yet, some adaptation is needed. First, instead of assigning one score per criterion, each question should be given a rating. Secondly, each question should also be answered by written reviews instead of simple observations. By doing so, the written reviews and the scores will be clearly linked, the former justifying the latter. Concerning the evaluation results, it is important to represent them in a relevant and usable way. Special care should be taken to not over simplify the results as this might mislead the client. The client should be able to read easily the evaluators' results and compare them if more than one seismic retrofitting scheme has been proposed. One of the most effective options to do so is the use of a spider diagram. This allows a generic overview of the seismic retrofitting impact on architecture while also capturing each individual assessed architectural criterion. The latter will be represented on the diagram with a score based on the average of the scores assigned to the questions.

The evaluation system is planned to be developed as a software, facilitating the evaluation process and results examination. It will thus be possible to analyse in more detail each criterion by clicking on it in order to reveal its related questions, their scores (forming the average score of the criterion) and the written reviews (Figure 5).

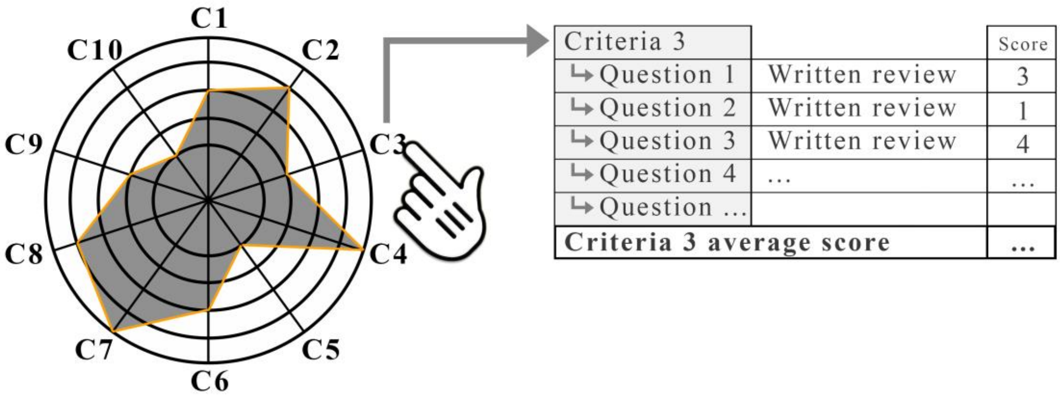

Figure 5. Evaluation results presented as a spider diagram. Each criterion contains the written reviews and scores assigned to each of its questions.

4 CONCLUSION

Architecture is an important issue that needs to be considered by designers as well as clients when planning to seismically retrofit earthquake-prone buildings. The consequences of the presence of seismic components on multiple aspects of architecture should be analysed and considered as much as other stakeholders' long-established preoccupations, such as cost, building disruption and level of seismic performance.

Due to the uniqueness of each earthquake-prone building and of the selected seismic technique(s), an infinite combination of retrofitting designs can be generated, each with unique architectural consequences. In order for designers to be effective in their design process, it is necessary for them to be able to consider the advantages and drawbacks of any potential scenario. Yet, this kind of task cannot be undertaken with existing established publications and guidelines because of their lack of content and flexibility in analysing specific seismic retrofitting solutions.

Some rare existing evaluation systems, such as the ones developed by Nishizawa and Cattanach et al., have started to take architectural concerns into account. They remain limited but are a valuable source for the design and development of a more effective evaluation system oriented toward architectural issues.

This new proposed evaluation system will also rely on architectural design competitions' assessment processes, especially the use of criteria and questions. This will allow the generation of a common framework for the evaluators to refer to when assessing a project, dialoguing and taking decisions. The use of written reviews linked with scores will allow global as well as detailed understandings of the impact of any seismic retrofitting scheme. To avoid misleading the client in understanding the evaluation results, the use of a spider diagram will allow a more comprehensive and relevant understanding of the evaluation outcomes.

Whether seismically retrofitting heritage or non-heritage buildings, structural engineers and architects have a responsibility to respect the existing architecture and ensure that the new architecture to emerge corresponds to the client's expectations. Preserving and enhancing existing buildings in both architectural and seismic engineering aspects is critical as they contribute to the economical, cultural and visual identities of their communities.

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