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Educational initiatives

Sustainable construction with repurposed materials in the context of a civil engineering–architecture collaboration

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ABSTRACT

In order to respond to the expected scarcity of fossil fuels, sustainability is incorporated into the curriculum of civil engineering and architecture students with a particular emphasis on: new technologies, new materials and energy efficiency in buildings. Today, the challenge of tomorrow is enhanced by the fore coming scarcity of raw materials. In addition, sustainable construction of new buildings has to be thought without provision of new raw materials. One promising solution for future building construction, considering the limited material resources, is to repurpose materials that have already been manufactured. This relies on a shift of mentality towards reusing/recycling of materials instead of discarding them. This paper presents a pedagogical activity focusing on the use of repurposed materials. The paper describes the rationale behind the re-use of materials and details how the gap between civil engineering and architecture perspectives has been bridged in order to the "design-build" practical workshop. The results of this sustainability exercise are presented through the description of two major constructions erected from a mount of waste in Marseille (France).

1. Introduction

The concept of sustainability was first defined by the Brundtland Commission of the United Nations in 1987 as the "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

During the last 30 years, there have been unprecedented increases in development, industrialization and population growth. These have raised concerns that the resulting damage to the earth's environment and quality of life for future generations will be irreparable (Carley and Christie, 2000). Universities have a moral role in transforming societies through in helping society to create a more sustainable world (Waas et al., 2010). In the last two decades, an increasing number of universities have been engaged in Education for Sustainable Development (ESD) (Lozano et al., 2013; UNESCO, 2013). Education is the main motor for a shift in mentality, as it has been the case for ethics in work incorporated in engineering curriculum (Spier, 2012). In particular, special issues of scientific journals were dedicated on ways to incorporate sustainability into the engineering and architectural education (Lozano García et al., 2006; Haselbach, 2011). Two papers in the later issue proved to be beneficial for multidisciplinary or interdisciplinary interaction in sustainability courses for enhanced student learning (Bhandari et al., 2011; Wolcott et al., 2011). These papers indicate that students learned interdisciplinary teamwork, communication skills and how they could incorporate the input of different disciplines into a global reflection.

In New Zealand, during 2004 and 2007, surveys were conducted on practicing engineers and architects to assess the quality of the inter-disciplinary relationships and the perception of their professional collaborators (Charleson and Pirie, 2009). The results of these surveys show that architects often complained about the conservatism and lack innovation demonstrated by engineers. This is in particular observed in structural problems, where architects, find more than one solution, while engineers tend to apply a single standard solution. On the other hand, engineers complained that architects lack an adequate structural and mechanical understanding.

Effective collaboration has to be embedded in the curriculum to bridge the gap between these two professions and to achieve a better result in terms of aesthetics and stability. This, however, it is still difficult since disciplines in higher education are often siloed.

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In the majority of universities around the world, the division between architectural and civil engineering disciplines is not only physical but also applies to the curriculum.

This is particularly true in France, where the silos extend all the way up to the ministries: Ministry of Culture is in charge of Architecture's curriculum while the Minister of Higher Education and Research is responsible for that of Civil Engineering curriculum. This division is detrimental to the relationship between the construction industry and the design industry as they have not been taught the same language and do not share a common vision. It has been acknowledged that, in most cases, tertiary education does not properly prepare young professionals for collaborative work between disciplines (Charleson and Pirie, 2009).

To address this issue, some institutions started to offer multidisciplinary initiative courses. During 2007, at Grenoble (France), the "Conception collaborative" course involved master students from the architectural school (ENSAG) and from civil engineering (UJF). In this course, students acted as both architects and engineers with the aim of developing a project for the refurbishment of a building. This course showed that, to improve efficiency, collaborative work is required from the conceptual phase of the project. This was already pointed out by Schlaich (2001) who observed that the relationship between the two parties is often marked by miscommunications since Architecture and Civil Engineering students do not speak the same language.

As discussed previously, the teaching of sustainability in universities is at an early stage in many institutions. In fact, sustainable development is a global challenge and needs to be incorporated in both civil engineering and architecture. It would also be an opportunity to enhance the rethinking of curricula by developing active collaborations. The present paper proposes a new example of a pedagogical exercise which bridges the gap between both disciplines within a new course of sustainable constructions.

In Civil Engineering and Architecture curricula, ESD is often associated with "green building" through the use of energy performance in building techniques (Cantalapiedra et al., 2006). Nevertheless, this vision could be questionable as it seems to be a short view of sustainable problems, needing new products/materials and finally, in a long view much more wastes. Sustainability seems more achievable by the reduction of waste production. In universities, it is a challenge for facilities management directors who develop waste management strategy (Zhang et al., 2011; Wright and Wilton, 2012) but usually, it is not included within a global reflection of design perspectives in Civil Engineering and Architecture courses. However, about one-third of construction waste could essentially arise from design decisions (Osmani et al., 2008). In the framework of ESD, a course on the topic of waste needs, therefore, to be proposed to students. To highlight the challenge of waste reduction, one promising solution is to repurpose obsolete materials that have already been manufactured. But repurposing materials is strongly associated with poverty and it will take a radical shift of mentality for sustainability to be fully achieved. This might be possible through appropriate education of upcoming engineers and architects where the different facets of building with repurposed materials are taught in the curriculum. As the challenge for educational institutions is not simply to teach concrete facts about the environment a "design-build" workshop is ideal to permit a unification of theory and practice (Warburton, 2003) and to allow values to be lived out and debated. Some pioneer work has already been done in the 1970s in the School of Architecture (Pawley, 1982, Rensselaer Polytechnic Institute, USA) and since the 1990s by the Rural Studio (Oppenheimer Dean and Hursley, 2002, 2005) in the School of Architecture, Planning, and Landscape Architecture (Auburn University, USA). However, teaching and/or building with repurposed materials still remains a rare activity. Furthermore, only architectural institutions drive these pedagogical experiences.

Table 1
Learning theoretical and workshop modules.

Theoretical module	**Submodule 1: How determine if a product is sustainable or not?**	**Submodule content**
	1.1 Energy balance	- Solar photovoltaic cells
	1.2 Raw materials consummated	- "Green" constructions and embodied energy
	1.3 Life cycle assessment	- The end-of-life (disposal phase)
	1.4 Overview of the for coming scarcity of raw materials	- Fossil fuels, - Metals
	Submodule 2: Definition of repurposed material	**Submodule content**
	Reduce, Reuse, Recycle and Repurpose	- Reduction waste materials by design, - Reuse material and remanufacturing, - Recycle waste materials, - Repurpose waste materials
	Submodule 3: impact of repurposing materials on building habits	**Submodule content**
	3.1 State-of-the art in building with uncommon materials	- Pioneers works (Pawley, Reynold, Rural Studio), - Contempory works in the whole word
	3.2 General mentality over waste materials	- Why mentality needs to change?
	3.3 How to change the mentality?	- Aesthetically seduction and logical mechanical stability
	Submodule 4: the necessity for collaboration	**Submodule content**
	Historical division between CE and A	- Collaborative work needs to be effective from the conceptual phase of the project.
Workshop module	**Submodule 5: workshop to turn a conceptual design into a full-scale construction project**	Submodule content
	5.1 Preliminary works	- To find, store and classify materials, - Site Analyzing
	5.2 Initial designs	- Discipline design process, - Discipline language, - Drawings and calculations, - Waste reduction by design, - Spatial organization
	5.3 Prototype phase	- Feasibility and difficulty to realized initial designs
	5.4 Construction work	- Understanding of the building process, - Respect of the time table

The present paper proposes a new model of a practical pedagogical activity built around "design-build" sustainability workshops with unconventional construction materials. These workshops, proposed to civil engineering and architecture students, revolve around repurposed materials and have three objectives: (1) to rethink the sustainability in building bearing in mind the unavoidable future scarcity of raw materials, (2) to bridge the gap between civil engineering and architecture disciplines by an active collaboration on a "hands on" project, (3) to increase the students awareness about sustainability and to improve the knowledge on this topic. The paper also demonstrates how repurposed materials can be an effective response for integrating an effective sustainability in education.

The paper begins with the curricular framework. The theoretical module and the workshop module are then described to share the