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Knowledge-based parametric tools for concrete masonry walls: Conceptual design and preliminary structural analysis

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ABSTRACT

The paper explores the potential uses of parametric modeling to embed construction and structural design knowledge in the form of generative rules and feedback rule-checking functions. The goal of the research reported here is to relate knowledge regarding constructive and structural principles during conceptual design in order to improve early decision-making. For that purpose we have developed a series of functions to guide conceptual design exploration by providing timely evaluation of design alternatives. The research focuses on load-bearing concrete masonry walls, and on basic requirements for doubly curved walls as a design case study. The research extends the Building Object Behavior methodology developed by Lee and others to elucidate, translate and implement design expertise into parametric rules and behaviors. The paper introduces the methodology in the context of a prototype modeling tool for early-stage design of concrete masonry walls and discusses the implications of a parametric modeling approach for conceptual design and collaboration.

1. Introduction

Practitioners and researchers from different design disciplines have recognized that concurrency of knowledge and interdisciplinary collaboration during the design process are fundamental conditions for the development of better products [1–7]. For this reason many computer applications have been developed in various areas to support integration across entire product development cycles. However, many of these tools specialize in supporting late design development activities, such as detailed engineering analysis or simulation and optimization. Relatively few have been successfully developed to support conceptual design [8].

Early conceptual design is important because the most critical features that impact product life-cycle performance are normally decided at this stage [9]. Despite the differences among design disciplines there is a common agreement on the relevance of the conceptualization step, the need for a re-distribution of efforts towards early knowledge integration and the general lack of computational support during early decision-making. Illustration 1 provides an overview on the relevance that different authors have assigned to early stages of design. While Fabrycky emphasizes the need of foregrounding knowledge about economics and life-cycle-costs early in the decision process [10], Wang focuses on the role of computational tools, and their potential to support conceptual design [8]. In the domain of building design MacLeamy refers to the need for the redistribution of stakeholders efforts to improve the outcomes of a design process. This idea is the basis for the Integrated Project Delivery (IPD) method [11] (Illustration 1).

In the Architecture, Engineering and Construction (AEC) industry, the causes of the unresolved issue of effort re-distribution is closely linked with this lack of tools to support effective knowledge integration at early design stages. Despite the American Institute of Architects (AIA) Integrated Project Delivery (IPD) Guide recommendation for the adoption BIM technologies in order to obtain the full potential of IPD processes [11], the fact remains that current BIM tools still have a limited ability to address concurrency and integration at early design phases.

At the core of this limitation is the problem of representation. Conceptual design in architecture is a creative process that has to provide solutions for ill-defined and incomplete problem requirements [12]. Early-stage design is an ambiguous and intuitive process that requires the use of highly flexible, unstructured and generic representations. On the other hand integration with analytical tools requires some level of formalization in order to obtain useful feedback [13]. The dichotomy between generic and formal representations has been discussed by Turk. He argues that formal, structured models, such as those at the core of BIM[1] building representations are in contradiction with creative design processes [14].

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[1] More specifically, Turk refers to Building Product Models defined by a conceptual schema.

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