



Automated optimization of formwork design through spatial analysis in building information modeling

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ABSTRACT

Formwork construction for reinforced cast-in-place concrete work is costly, often time-consuming and complex to plan and design. Even though the process of calculating the proper formwork design is lengthy and complex, the responsibility is usually left to a field manager/engineer which may not have enough time and resources identifying all possible options to select the most effective formwork.

The design aspects that go into formwork include several parameters such as concrete pressure, bending, deflection, and horizontal shearing. Even though there are equations and calculations for each of those parameters in the design of concrete formwork, the process of performing the calculations for each concrete formwork application is still lengthy. Therefore, construction managers often rely on their previous work experiences and apply similar formwork designs for most situations.

By developing a BIM (Building Information Modeling) based automatic formwork design system, this research aims to optimize the formwork design process required to perform the calculations for the design of the formwork by automatically extracting the properties and data from a BIM model. The case study shows that the proposed formwork design approach successfully automates the formwork design in BIM modeling using IFC extension by comparing the different materials and costs. The result of the case study reveals that the efficiency of the formwork design process could be greatly improved by utilizing the proposed formwork design system.

1. Introduction

Concrete formwork can be costly, accounting for up to 40–60% of the cost of cast-in-place concrete [21]. There are often opportunities to implement a more cost effective formwork design for the specific application, but because the process of calculating the proper formwork design is lengthy and complex construction managers often have difficulty identifying all possible options to choose the most effective design option. In fact, there is often more of a focus on the design of permanent structures, leaving not much room for temporary structures such as concrete formwork [1].

In general, concrete formwork is normally designed to provide support for freshly placed concrete until it can support itself [2]. Attempting to make the formwork design process more effective much of the previous research relied on traditional 2D drawings which consist of the segments of lines, curves and points. However, the 2D drawings in information processing have been difficult. This research utilizes 3D intelligent objects stored in BIM models for extracting/retrieving the

information needed to automatically identify a proper space on a building surface. By doing so, this research also attempts to optimize a formwork design through multiple comparisons in computer simulations. BIM used in this research represents a design as combinations of objects that store information on their geometries, relations and attributes and the objects are defined as parameters and relations to other objects.

In BIM data schema [3] there is a rich set of definitions in representing almost every part of a physical building with 766 object entities but very little in temporary structures such as formwork or scaffolding facilities. Thus, this research extends the current BIM scope and proposes an extension to the current IFC (Industry Foundation Class) schema [4] and develops new entities such as IFCplywood, IFCstud, and IFCwale for concrete formwork design. By utilizing the components of a concrete formwork system, the prototype developed in this research extracts the properties and data from the building design model, automatically identifies the proper areas of concrete walls where the concrete form is needed to be placed and perform the

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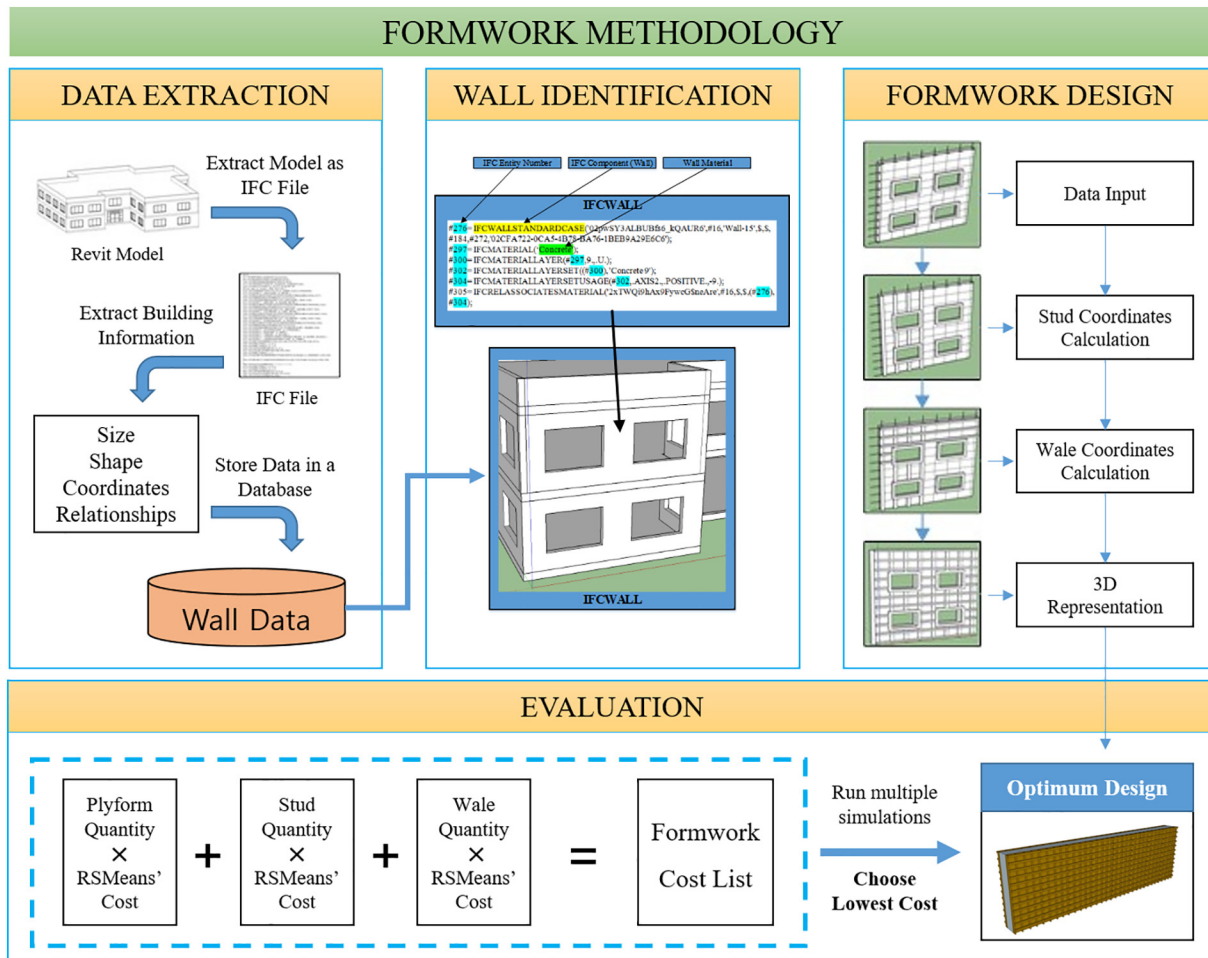


Fig. 1. Overall process in automatic formwork design.

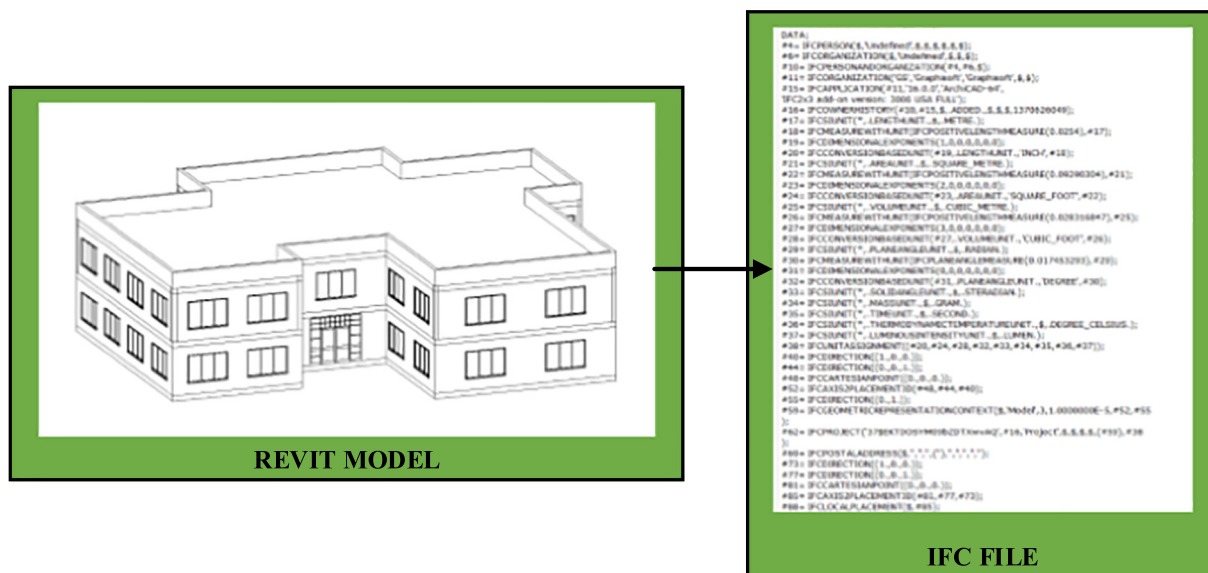


Fig. 2. Conversion from Revit model to IFC file.

calculations in the formwork design process. Then, the proposed concrete formwork system finally optimizes the formwork design by comparing multiple different factors in computer simulations. The proposed method of formwork design simulation is through the use of

open-BIM standards. The international standard used for the research is IFC, which is established in the building design and construction industry. IFC is based on ISO 10303 and is an international standard for data exchange in building design and construction that is compatible

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