DISPUTATION

COMPUTATIONAL METHODS IN CONCEPTUAL STRUCTURAL DESIGN

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Abstract

Conceptual design is the first phase in the design process in which all the requirements and design objectives are synthesized into conceptual alternatives. In practice today, major decisions regarding the buildings function, massing, and overall form are usually made during the first phase. Considering structural performance requirements during conceptual design enhances interdisciplinary interaction, and creates a visual link between form and numeric performance evaluations, reducing work on poorly performing solutions. To include structural performance in conceptual design requires, amongst other things, the availability of tools such as simulation software, suitable for conceptual studies.

The aim of the research is to develop new efficient methods and procedures for supporting an interactive and iterative design process that includes engineering aspects. By integrating engineering knowledge and physical aspects in the developed tools, a more efficient and better-adapted design process can be obtained. Supporting an interactive and iterative design process requires new interaction models and numerical approaches in the tools used.

The research is limited to three different areas. The first area is related to conceptual studies for reducing ground borne wave propagations in an urban scale. A tool is developed for simulating forms with masses placed on top of soil in an urban scale and studying the resulting effect that the forms have on the propagating waves. The tool uses the finite element method and studies the vibration reduction effects in the frequency domain. Paper A presents the tool and draws some conclusions related to the levels of vibration reduction for various patterns, showing that some patterns are effective in mitigating the incoming vibrations. The approach in the tool makes it possible to obtain results in minutes, allowing the user to generate many alternative proposals quickly, and act as an aid in brainstorming sessions.

Papers B and C focus on a recent extension of the finite element method, isogeometric analysis, that is the subject of the second area. The implementation of isogeometric analysis with membrane elements for form finding of efficient shapes for shells is presented. The dynamic relaxation method is used for finding the static solutions. The method is employed directly on design geometry, which is described by non-uniform rational b-splines (NURBS), without the need for any further discretization. Paper B investigates various selections of mass and damping for the dynamic relaxation method with NURBS based membrane elements. The resulting methods are implemented in two plug-ins for the computer aided design applications Rhinoceros 3D and Grasshopper 3D, of which the former is presented in Paper C. The method describes form found geometries well with very few elements and can be used to explore different efficient shapes for shells very rapidly and directly in design software, and is thus suited for design explorations.

The third area is about graphic statics -- an old method which is again gaining popularity due to progress in CAD and computational methods. The strength of the method is in an intuitive and graphical representation of form and the internal forces of static equilibrium, which are presented in two diagrams -- the form diagram, and the force diagram. The current research efforts in graphic statics aim to apply the method as a design tool rather than to use it for analysis. A second aim is to investigate the benefits of computer based graphic statics. Paper D presents a root finding approach for computing a form diagram based on manipulations of a force diagram. Paper E presents an algebraic method for computing form diagrams based on force diagrams. Paper F presents an application of graphic statics for automatically generating initial strut-and-tie patterns.

Key words

conceptual design, conceptual structural design, ground-borne vibrations, form finding, optimization, dynamic relaxation, graphic statics, reciprocal figures, strut-and-tie, finite element method, isogeometric analysis, NURBS, CAD, numerical modelling,

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