New Simplified Thermal and HVAC Design Tools For Building Designers

by

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Summary

Title : New simplified thermal and HVAC[1] design tools
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Building designers are increasingly pressured to design buildings with high standards of energy efficiency, performance and comfort in the shortest possible time. Computer design tools have a tremendous potential for aiding designers in achieving the above design objectives. However, designers generally find the existing tools difficult to use. The potential of these tools is therefore still largely untapped, and the need for simplified design tools still exists.

Thermal efficiency of buildings and HVAC system selection are two areas that can greatly benefit from simple design tools. These aspects have a large influence on the socio-economic success of a building, but due to the complexity and time required for analysing the various options, they usually do not receive the necessary attention. A simplified thermal design and HVAC system selection tool was developed during this study to address this need.

Thermal efficiency of a building is largely determined by architectural design decisions made early in the design process. Detail required by existing simulation tools make them impractical for use by architects. Input complexity could however be significantly reduced for the new tool by applying Pareto's law of distribution. A sensitivity analysis was performed to identify the critical input parameters on which to focus.

An extensive verification study was performed to ensure that the simplification assumptions are valid and that the tool could be used with confidence. A South African building design rating

[1] Heating, Ventilating and Air Conditioning

scheme was also developed to further enhance the use of the tool. The scheme rates a building design depending on its HVAC system size requirements.

Ideally, HVAC selection also requires a detailed analysis to compare the various available systems. In practice, system selection is usually based solely on initial cost or the designer's experience. A simplified preliminary analysis can however be carried out by estimating system performance characteristics using expert knowledge. A preliminary rating and selection tool was developed by using a numerical ranking method as an expert system shell.

Selection criteria used as basis for comparing the various systems depends strongly on the building developer's requirements, and must therefore be taken into consideration. This is done by incorporating the whole design team in ranking the importance of attaining certain design goals. The selection tool thus further serves as a communication aid.

In order to demonstrate their function, the above simplified design tools were applied to design a hypothetical office building. Using these tools it was possible to perform an extensive building and system analysis without the need for detailed information. The required HVAC system size could be reduced by as much as 60% by applying the thermal analysis tool. The main benefits of the selection tool are that designers do not focus only on familiar systems, and aids designers in establishing the needs and requirements of the building developer.

It is believed that the new tools will contribute towards improving building efficiency and indoor comfort. This study shows that design tools need not be complex or difficult to use in order to be beneficial to designers.

Opsomming

Titel : New simplified thermal and HVAC design tools
Promotor : Prof. E.H. Mathews
Departement : Meganiese en Lugvaartkundige Ingenieurswese,
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Graad : Philosophiae Doktor
Sleutelterme : Voorlopige gebou ontwerp, Gebou termiese doeltreffendheid, Gebou energie klassifikasie, Lugreëlingstelsel seleksie, Rekenaargesteunde ontwerpsgereedskap

Daar word al hoe meer van moderne ontwerpers verwag om in die kortste moontlike tyd geboue met hoë energie effektiwiteitstandaarde en behaaglikheidsvlakke te ontwerp. Rekenaargesteunde ontwerpsgereedskap het die potensiaal om ontwerpers se taak te vergemaklik en dit met sukses af the handel. Die potensiaal word egter nog nie ten volle benut nie omdat meeste ontwerpers die gebruik van bestaande pakkette as veeleisend en moeilik ervaar. Daar bestaan dus nog 'n behoefte vir eenvoudige ontwerpspakkette.

Termiese effektiwiteit van geboue en die keuse van lugreëlingstelsel is twee areas wat kan baat by eenvoudige ontwerpspakkette. Die items het 'n groot invloed op die sosio-ekonomiese sukses van die gebou. Daar word egter nie altyd genoeg aandag aan die aspekte gegee nie omdat dit 'n komplekse en moeisame proses is om al die variasies te analiseer. 'n Eenvoudige termiese analise en lugreëling seleksie pakket was ontwikkel om in die behoefte te voorsien.

Termiese effektiwiteit van 'n gebou word grotendeels bepaal deur argitektoniese besluite. Bestaande analise pakkette is egter onprakties aangesien hulle baie detail benodig. Die nuwe termiese analise pakket is egter aansienlik vereenvoudig deur gebruik te maak van Pareto se distribusie wet. Die beduidende parameters was geïdentifiseer deur 'n sensitiwiteit analise uit te voer.

Die pakket is verder uitgebrei deur die ontwikkeling van 'n gebou ontwerpsklassifisering stelsel vir Suid Afrikaanse geboue. Effektiwiteit van die ontwerp word gegradeer volgens die grootte

van die benodigde lugreëlingstelsel. 'n Omvangryke verifikasie studie was gedoen om te verseker dat die nuwe pakket met sekerheid gebruik kan word.

Die keuse van 'n lugreëlingstelsel behoort ook gebaseer te wees op 'n breedvoerige analise om die toepaslikheid van die verskillende stelsels te vergelyk. In praktyk word stelselkeuse meestal gebaseer slegs op eerste koste of die ontwerpers se ervaring. Dit is egter moontlik om 'n voorlopige analise te doen deur stelseleienskappe en werkverrigting af te skat gebaseer op stelsel kennis. 'n Voorlopige stelselkeuse pakket was ontwikkel wat gebruik maak van bogenoemde tegniek en 'n eenvoudige numeriese klassifisering stelsel.

Stelselkeuse word sterk beïnvloed deur die vereistes van die gebou se ontwikkelaar en die' moet dus ook in ag geneem word. Dit word gedoen deur die hele ontwerpspan te betrek in die bepaling van watter vereistes die belangrikste is om te behaal. Stelsels word geklassifiseer ten opsigte van hoe goed hulle die vereistes nakom. Die pakket dien dus ook as 'n kommunikasie hulpmiddel.

Die gebruik van die nuwe pakkette was gedemonstreer deur hulle aan te wend in die ontwerp van 'n tipiese kantoorgebou. Dit was sodoende moontlik om 'n gedetailleerde gebou en stelselanalise uit te voer. Die benodigde lugreëlingstelsel kon met 60% verklein word deur gebruik te maak van die termiese analise pakket. Die voordele van die stelselkeuse pakket se is dat meer stelsels maklik vergelyk kan word en dat die kommunikasie tussen die kliënt en ontwerper verbeter.

Die nuwe pakkette het die potensiaal om 'n groot bydrae lewer in die ontwerp van energie effektiewe en behaaglike geboue. Die studie toon aan dat ontwerpspakette nie kompleks of moeilik bruikbaar hoef te wees nie.

Contributions of this study

The following main contributions were made by this study:

- A new thermal design tool was developed for use by architects. The tool addresses the need for incorporating architects in designing new energy efficient buildings. Its development followed an innovative approach towards reducing the input complexity hampering the use of existing thermal design tools.

- A new building thermal efficiency rating scheme was developed for South African residential and office buildings. Using this rating scheme designers can quickly compare and evaluate the efficiency of their design without the need for a detailed analysis.

- The thermal design tool was extensively verified in order to establish confidence and credibility in its use.

- A new preliminary HVAC selection tool was developed. It combines the simplicity of numerical ranking methods with the proficiency of expert systems. It also addresses the need for better communication between the different design team members.

- In the long run, the use of the new tools could potentially contribute greatly to the design of new energy efficient buildings without further complicating the existing design methodology.

Preamble

The main body of the thesis consists of eight chapters. Each of these chapters, with the exception of Chapter 8, is written in the form of a journal article including its own abstract, introduction, main body, conclusions and references. Each chapter therefore can be read on its own or in the broader context of the study. To improve readability, all appendices are included at the end of the document.

In Chapter 1 the needs and trends in building and HVAC design tools are identified. This formed the basis on which a new thermal design tool for architects and a simplified preliminary HVAC selection tool was developed in Chapters 2 and Chapter 5 respectively.

In Chapter 3 an extensive verification study was performed in order to verify that the simplification assumptions are valid, and to establish confidence in the use of the new thermal design tool. To further facilitate the use of the tool, a new South African residential and office building rating scheme is presented in Chapter 4.

In Chapter 6 the necessary system rating factors are provided for the preliminary HVAC selection tool.

The application of the two simplified design tools was demonstrated in Chapter 7, and Chapter 8 presents recommendations for further work.

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