Support of Structural Design

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Abstracts

Heute wird verstärkt versucht, die CAD-Unterstützung des Architektenentwurfs in immer früheren Leistungsphasen anzuwenden. Der entwerfende Architekt muß hierbei eine VieIzahl unterschiedlichster Einflüsse beachten. Dieser Beitrag beleuchtete ein aktuell laufendes Experiment mit einem einfachen System zur Auffindung überschlägiger Bauteilabmessungen. Zur Anwendung gelangte AutoCAD 10.0, programmiert wurde in AutoLISP mit Ausblick auf die künftige Anschlußmöglichkeit von C unter AutoCAD 11.0.

L'aide du CAO en architecture est plus en plus faite dans des phase jeunes du projet. On a besoin des instruments spéciaux pour réussir. L'architect doit faire attention d'une multitude d'influences differentes. Cet exposé met un coiip d'oeil sur une expérience courante avante pour but de supporter l'estimation d'une construction d'un projet et ces dimensions. Le système est réalisé en AutoCAD 10.0, usant AutoLISP en perspective d'user la C-interface sous AutoCAD 11.0.

Abstract

The tendency of using CAD-systems in the early phases of architectural design involve the need of advice tools to support the design process. Many influences have to be managed by the designer. This paper catches a glance on an experiment presently running, aiming at the support of structural design. The system is implemented on AutoCAD 10.0, using AutoLISP with the outlook on future C-interfacing with AutoCAD 11.0.

Introduction

Watching architects doing their design-work they mostly start with exploring the functions their project has to satisfy and try to fit their first studies in the environment in order to get the first ideas of what the result would he going to look like. (1 apologize deeply simplifying this enormously creative act of art in that crucifying way.) This paper does not intend to go into details as for different theories of achieving an early phase of design.

Having dealt with a large number of practicing architects consulting them in their design work - and with an enormously large number of students of architecture in their early pains of getting acquainted with the most primitive principles of statics and structural design, 1 got a certain idea how complex the process of design tends to be.

In many cases circumstances force the designing architect that he involves the specialists (heating plumbing, air-conditioning, water-supply and last not least the structural engineer) in a rather late phase of the design process. In many cases this is because there are no contracts given to the specialists in that early phase - and mostly people feel a certain discomfort to work without some good perspective to get it paid.

That is why it comes to most unpleasant and expensive amendments when the project has already become fairly detailed and the specialists start their destructive work on the artful result of architectural creativity. Lots of beams will become larger and destroy the impression of immaterialized lightness, which seems to fascinate architects more than anything else. Large sectioned airducts force a revision of a variety of design decisions.

And more than that: Certain revisions applied by one specialist cause a considerable number of difficulties in the domains of other specialists.

Usefulness of early support in the design process

The need of having a "thumb-rule" expert available to not getting wildly into irrational and unrealistic projected sizes of the main building elements has ever since emerged. We might object, that a highly efficient architectural office has enough experience – or has specialists employed - to manage this without the experts' aid. That is obviously correct. And some students of architecture have made experiences of their own, having achieved better results in their design studios if they simply ignore the advices of the structural designer. But all this cannot be a serious motive to deny the usefulness of some advising support in the early process of design.

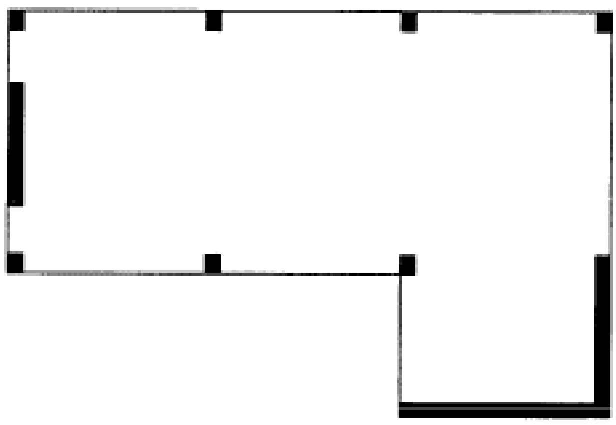
Without considering the contradictory (kontrovers geführten Diskussionen) opinions in detail whether or not the design students should apply for structural advice - creativity and intuition of the unexperienced brain might be inhibited severely - the -structural design adviser- could he of reasonable help, namely in Schools of Architecture where there is a certain lack of motivated structural design teachers, who would produce some natural "structural problem consciousness- in the young students.

To avoid another potential source of being misunderstood: The following layout of an advice-tool cannot replace the thorough structural analysis of all building elements.

Getting started with some ideas

The initial idea of this experiment was supporting the design activity in the stage of getting started with the first thoughts about dimensioning the main structural elements. At that time we might have a sketch or probably already a data model in some way or other.

The really striking fact is that getting started with a structural advice the necessary input is very limited - we accept this thankfully considering the critical voices of CAD-users who are terrified by the lump of information one has to achieve at a much to early phase. Observing a really efficient structural advising session the first thoughts are dedicated to the overall stiffening system of the building. A sufficient number of shear walls in useful positions and the advice to avoid columns as part of the stiffening system is a nice thing to know very early.



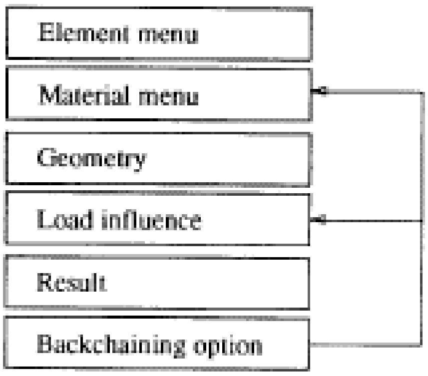
If there are no geometrical data available at that time it will be appropriate to start now. Even a line-sketch done with a CAD-system will do. I should mention that the following experiments were done with AutoCAD as for having mostly reasonable data-interfacing to a variety of other CAD-systems via DXF and - most important -having an interface to AutoLISP and C (C-interface only since AutoCAD version 11.0).

As I got started with AutoCAD 10.0 I had only the AutoLISP-interface and 1 felt content with that for the moment. Since having a lot of advantages by using C, 1 am sure that, after getting out of the experimental stage, C will be the better way to program those parts, where efficient performances of numerical operations are needed.

Back to the rudimentary data-model. Let us assume that there are grids with spans of beams and heights of columns roughly available, than the first thoughts may come up dealing with the structure that has to support the building. A most important condition seems to me that the decision, when or if at all the user wants to he advised by the expert is an entire user's option. He has to call the procedure and should easily proceed by help of some selection menus and the extraction of geometrical data by picking some reference points. Further conditions have to be efficient help options in all stages and after getting the results the option of backchaining e.g. to examine alternatives.

Operation Set

Having decided on the element of the expert's activity and having done a first choice on the material and characteristic geometry, the expert can start working. This is done by working down a set of menus and geometrical inputs out of the CAD-drawing which results at last in some return values given by the expert system:



beam	
column	
slab	
foundation	

element menue

steel	
wood	
concrete	
brickwork	

material menue

Let us have a look at some examples:

A reinforced concrete column

There a very efficient thumb-rule can he applied with

$$\underset{[cm^2]}{A_{column}} = \underset{[m^2]}{A_{load\ influence\ area}}$$

with

A_{column} cross section area of the column

$A_{load\ influence\ area}$ sum of load area

on all floors horn by the column.

Approaching the architectural design there is nearly no need to know the number and size of reinforcement bars, it is only important to get an as good as possible knowledge of the outline of the cross section.

All thumb-rules want to accurately follow some default values, which describe the result precisely within a certain range of feasibility which depends largely on the respective problem. Within this example we can see the following defaults:

material:	Concrete B 25
	steel BSt 500/550 S
geometry:	usual distance
	floor to floor of 2,50 m
cross section:	oblong with ratio LO: 2,0
	minimum 20 cm each side
loads:	10,0 kN/ml
	all included (dead + live load)
	only vertical, no horizontal loads

Discussing these values on behalf of the range of feasibility, we can point out the condition that there are no or very low horizontal forces as the most sensitive, followed by the geometrical default. Especially the existence of horizontal forces and with that of bending moments will cause severe influence on the size of the column. A column not only supporting the building loads but as well serving as horizontally stabilizing element can show factors up to 2.5 of the size of columns with only vertical loads. This should result in some screen message which points out exactly this default restriction.

The defaults used in material, cross section and vertical load cannot badly disturb the thumb-rule operation. Deviations of the default values can easily he covered by the amount of reinforcement.

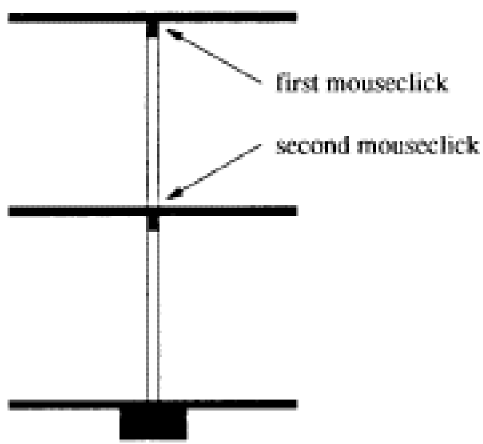
The sensitive input is covered by giving the load influence area and the number of floors. Just to check the position within the feasibility range we ask for the distance from floor to floor. The screen menu therefore will ask for the following information:

distance (floor to floor) (m)

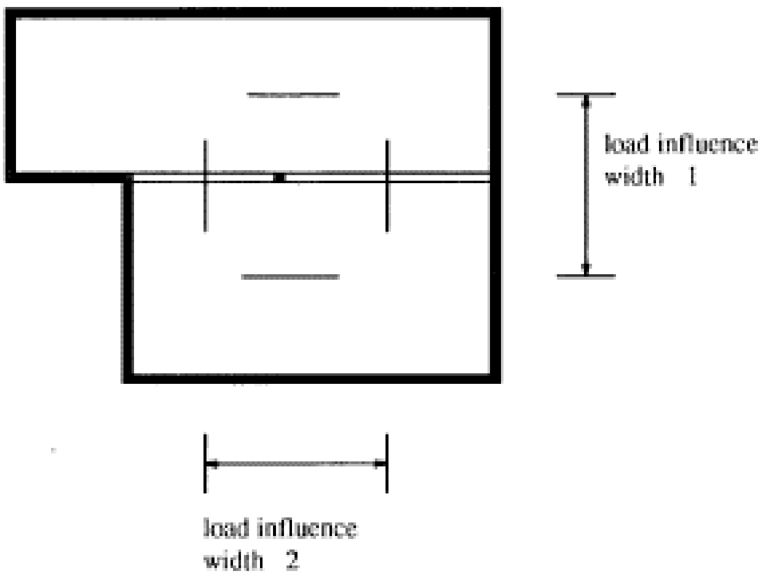
load influence area
length (m)
width (m)

number of floors

The first two input elements are given by mouseclicks without claiming particular precision. Difficulties come up if the load and/or the load influence area is not the same on all levels. Later versions will have an option to cover this.



height of column



A wooden or steel beam

We have made the experience that the application of the very rough thumb rule

$$d = L / 15 - L / 25$$

where

d	height dimension
L	span

is in many cases extremely misleading. Students don't hesitate to select the extreme border value (LP25), angrily pointing out that they have used the thumb rule they have heard in one of their lectures.

Using a more accurate advice which is observing the load influence area and deformation restraints we see that there is no big difference in the operation procedure between a wooden or a steel beam. The expert can work out very easily rather good results by using

$$W = M / \sigma_{allow}$$

$$I = k \cdot M \cdot L$$

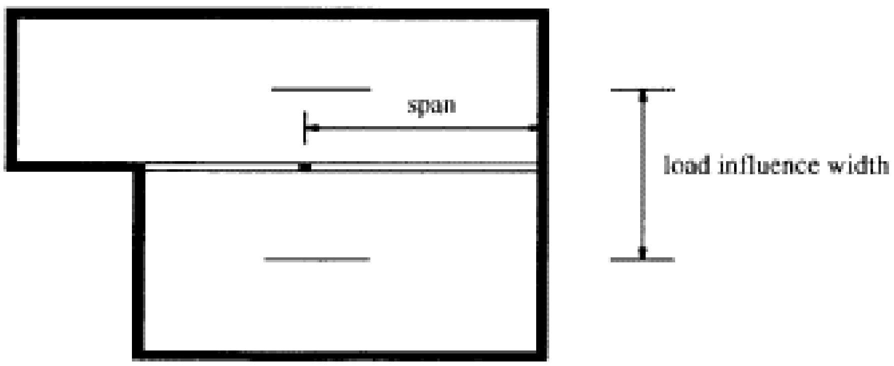
with

$$M = b \cdot q \cdot L^2 / 8$$

and

q	area load	)	
b	load influence width	)	input values
L	span	)	
M	bending moment	)	
W	ratio of resistance	)	internal values
I	ratio of inertia	)	
σ_{allow}	allowable stress	)	

As we can see immediately, the span L is the most sensitive value, followed by the less sensitive values of the width of load influence and the load itself. All other parameters have fixed values only dependent on the material selected.



recommended section: IPE 220

A reinforced concrete beam

Prof. Grimme - as teacher for construction design at the University of Technology in Munich - has developed a very handy thumb-rule giving approximate estimations to the size of reinforced concrete beams.

$$d = L / 20 + 20 \ [cm]$$

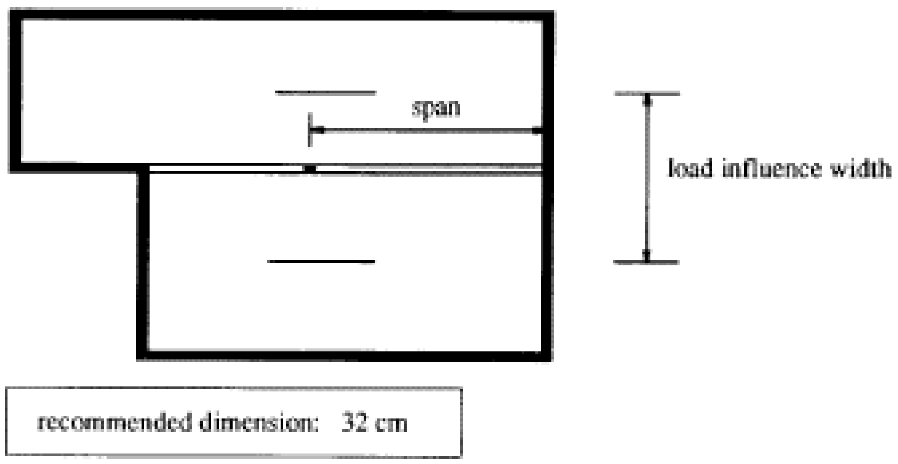
with

d construction height (cm)
L span (cm)

under the following conditions (default values)

material:	concrete B 35
	steel BSt 500/550
geometry:	distance between beams < 5,0 m
	cross section ratio 1:4
load:	10,0 kN/ml

It is amazing that within the usual ranges the height of the reinforced concrete beam is only depending on the span - a condition we are tending to fight in case of wood or steel beams. With the exception of the load influence value, all values are rather well-behaving, whereas the spectrum of load influence may cause remarkable corrections to the result of the thumb-rule. This amendments may be added in a further step to sharpen the accuracy of the expert's result.



Getting Information out of the system

As mentioned above in chapter 2 it is of utter importance, when using "rules of the thumb" to provide the user with a variety of help-options, one of those being an exact information-set of the rules applied. The relatively easy-going and simple application of thumb-rules can only he achieved by using a set of parameters, which satisfy a large number of design-cases without reacting sensitively on a variation of those default-values within the range of feasible solutions.

The help-option -information- must supply the user with knowledge about the default values and the range-of-behaviour, where those values do not have a misleading influence on the result of the system. In many cases it will be necessary to maintain help-menus for further help, in order to give boundaries to some design events, e.g. the span of a slab with a given thickness, when there should be no ribs or beams.

It will be useful to provide a range of help that will he able to give further information in case of some not satisfying result. After calculating the dimensions of a wooden beam there will often emerge the problem, what chances are given to reduce the height of the beam. The expert should then come up with the default conditions one after the other and give advice for height reduction conditions, as e.g. continuous beams over several spans etc.

Conclusion and outlook

The examples shown above are first results of an experiment recently started. The outlines are done but layout of the performance and level of difficulty of the problems covered tend to be rather low presently. First experiences of the shown experiment are promising and it is rather easy to proceed to a first stage of structural expert system. It will he one of the characteristic features that the system will develop, starting with the simple elements as beams, slabs and-columns, ending up with truss girders, frames and space structures. There will be options to select a variation of accuracy steps as well.

Based on the same operational procedures we can predict some similar systems dealing with energy and heating problems etc. Many attempts have been made to cover all these influences in one single integrated building system. It seems that nowadays we are coming to terms with the fact that those attempts cannot be solved satisfyingly in one single system.

The performance of the advice tool will be strictly optional, there is no way of forcefully executing design amendments while consulting the system.

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