Architect and Structural Engineer in interactive design

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We are convinced that an interactive design process involving engineers and architects will create values to a project. Looking back there have been some obstacles, like a week's time for exchange of drawings with traditional postal services; manual calculation methods, which could not be spoiled on loose grounds like architect's sketches; different media – architect's drawings and engineer's numbers in tables; attitudes and traditional roles, implemented already in education.

Today most of these obstacles can be overcome and we have made a test.

We have used ArchiCad by Graphisoft and FEM-design by SKANSKA IT Solutions to test to make an interactive design.

Our conclusions are that exchange of information, drawings and other documents is more or less routine in praxis, and it works almost instantly. Computers make calculation faster and easier for the engineer. Though we would wish to have software which manages to do more rapid estimations. Even simulations such as of loads on a structure are practically possible. By using model based CAD the data can be used for transferring quantities for calculations as well as visualization of the design as a platform for collaborate analysis.

The technique is developed and usable but to gain acceptance and make use of it is also a matter of attitudes and of application activities in education.

***Keywords**. Interactive design: architects and engineers; model based CAD; simulations; structural analysis*

Introduction

The development of modern means of collaboration within planning groups was a tedious process. It is not a result of expectations, which were suppressed through decades, that we observe today a huge increase in collaboration.

In the first line this collaboration is forced by the new means of data exchange and by the dramatically shortening planning phases. Some twenty years ago some project plans could be sent from the architect's studio to the engineering office, questioning some reactions as for finding a structural concept or some dimensioning. With postal delivery in both directions and handling at the office it could take at least a week – and every body was happy with this.

Today your desktop beeps and announces the arrival of project data of some planning partner by e-mail. The partner is very far away, not even in the same country. The text accompanying the data expresses in maybe polite but surely determined words, that reaction is expected same day in the afternoon by sending back the data with additional information.

Even with calculators just one calculation took a lot of time and money, so you did not want to spoil it on loose grounds. It was then better to calculate on a late stage when everything was decided.

So, if the interaction could be done and everybody is forced in a hurry, we should accept the situation and turn the whole procedure to an advantage. This would mean in the first place that the quality of the "interactive material" should improve.

Reviewing past experiences

What is the difference from what is mostly done? We want to confine this to our experiences of the last years, where data exchange started to be common.

The interfacing itself caused a large amount of laments. Different CAD-systems were – and continually are – used within planning groups. The quality of data-interfaces has improved in the last time, so that in some cases intelligence is saved across the borders.

With some amusement we are looking back to the initial fights within the faculties where the traditionalists tried to smash every kind of introducing students to these modern working-methods. Those faculties, which gave early room to CAD-introduction were lucky; they escaped the blame of having not reacted in time.

Many students then tried to get CAD-knowledge on their own, lacking professional education and following the needs of the market. The damage, done to the studios and offices in practice, was immense. All those low-instructed persons, thrown into the process, caused much damage by simply transferring the methods formerly adopted on the drawing-board to the PC-screen.

The efforts that have to be done with structuring badly organized data can easily drown the prosperity of a job. For instance if the engineer gets a new set of design-data every four weeks and somebody has to work for days on these, in order to import them properly, it is quite obvious, that no success can be possible.

Architects' working method "sketching" is very much visual. It summarizes the traditional factors aesthetics, human needs and technical demands which are very different in values. One problem though is that this is only accessible to the architect. On the other hand, every attempt to make money the unit for comparison fails, as money effectively values the material side but is mostly inadequate when it comes to abstract matters such as feelings, social benefits etc.

The architect then gets into an analytic mode and visually evaluates if this was a good solution and if it causes new problems. The result of a calculation, manual as well as computer made, does not connect to the graphics of the architect! It is numbers in tables, which might demand an engineer to explain.

Modern means of collaboration within planning groups are improving and computers calculate faster and faster, so the "waiting time" is shorter. The computer does not mind to do it again and again which makes it possible to simulate what happens to a project as a parameter varies.

By using object based CAD software a data file is created which can be read and "understood" by a computer. This means that building elements' geometrical data can be used as input of quantities and sizes directly for calculations.

The geometry of the object-file makes it natural to work and analyze in 3 dimensions, which is better understood by anybody than the 2 dimensional views and language of drawings. It is also

possible to make the computer calculate another view, which makes it simple to simulate the moving of the object or the spectator.

A special development

CAD software has for a long time been concentrated to drawings but some companies have followed the technical development and today their CAD-systems are object based. In our case we have studied ArchiCad by Graphisoft and some development of FEM-design by SKANSKA IT Solutions. It is then possible to export a model file from ArchiCad, which can be translated and modeled by the engineering system FEM-design, where FEM is standing for Finite-Element-Method.

We have used this to exemplify and test our ideas. In our first example we designed a structural system for an office building and then in the second applied the concept on energy calculations for a residential house.

Example "Structural system of an office building"

Office-buildings request a high value of flexibility. The stories 1 and upwards are used for offices, which are under the pressure of a constantly changing organization and technical developments. The ground floor is used for a "generous" entrance hall and shops to be reached from the street. In the basement there should be enough parking facilities depending on the size of the building.

The bearing concept must incorporate these three different orders. It mostly consists of columns, slabs – recently more and more without any beams – and a sufficient number of shear walls, stabilizing the multi-story building. These can be built up partly by the walls around staircases and elevators, but the discussion here mostly comes too late and gets rather uncomfortable. The columns grow in load the nearer we come to the ground – but this rarely should be evident/visible, which becomes quite a challenge.

We, the Architect and Engineer, start the process of a test project by interactively finding a concept of a structural system and an architectonic idea which serves the three functional needs. By modeling in ArchiCad and export to FEM-design we could simulate different alternatives visually as FEM-design is 3-dimensional and can visualize constrains in colors as well as in animation.

This was helpful in many ways:

Analyses which we both could understand and use to clarify our standpoints and arguments. Also a great learning process!

Quick changes and new calculations – simply moving a column in FEM-design, and more extensive in ArchiCad and back to FEM-design.

Resulting in some alternatives to work on, but which already have considered both the architect's and the engineer's areas of knowledge, but naturally more or less impressed by either partner.

Example "Energy calculation on a residential building"

As owners or tenants of flats the cost and environmental impact of energy has got a rising interest.

The heating and climatization system is the most costly specific technical system in a house. It is depending on material factors as insulation etc. but also on design factors for instance orientation and facing of windows.

In this case we have not found a prepared transport of model data, but as the calculations are simpler we used a spread sheet as the software platform. The data needed were the areas of walls, windows and doors in different orientations, slab and roof areas and the energy factors of each sort of elements.

The "calculation module" in ArchiCad can find all these data. The ArchiCad calculation module is made to cover all possible uses of quantities but this also means that it takes some efforts to make it list the data in an understandable way. For exam-

ple, the orientation of wall can be translated from it's "direction", which is depending on the order in which the endpoints were set.

The list is exported/imported into a spread sheet which is prepared to process the necessary calculations and a result is presented by giving a value of the energy-loss or – more sophisticates – an estimate of the annual energy consumption. By repeating the process with the building in different orientations or with varying gave us a "numeric impression" of what happens to the energy behavior of our design.

An outlook on additional features

It is now possible to work on the same data file for different purposes. Exchange of data, IFC and standardization of building parts in for instance BSAB and other systems is rapidly making this real.

There are some cost estimation soft wares being developed and used, which work with data imported from model based CAD programs. TCM is one example which is using ArchiCad as its "quantity supporter". It works integrated as an "adds-on", a couple of windows within the CAD software.

Simulations still demand big computer power, but computers tend to get more powerful in an increasing speed. Especially when working on complex design models, the interaction by use of a common model offers substantial support. Frequently there is a lot of discussion about stabilization. If the engineer can "shake" the model, thus making visible the problem, planning partners may arrive much earlier at a satisfying design

Conclusion

Working on a common geometrical model without loss of intelligence (using interfaces) offers valuable help. This is realized most apparently, if there is afforded interaction between distant planning partners.

Arriving at a design model, where the engineering part is integrated validly within the architectural design, this may be a time-consuming and tedious procedure. Modern collaboration media together with the shown interaction between architect and engineer is not only of advantage to the planning process but inevitable, if distant partners are involved.

Calculation software is very much designed to calculate in late phases rather than estimations in the beginning. We hope that software developers will react positively on demands by architects and engineers who want to be able to just estimate.

The colored element parts or/and animated behavior for instance caused by loads in FEM-design is of principle interest! In the stage of a visual analyses of a solution a visual presentation of the calculable factors could be more compatible than a table of numbers. So as an architect and an engineer we would like to see already for the early models - on the computer – for instance how the costs and energy consumption differ by coloring of different parts of the building.

The modelling software has to take into account that the data should be usable for more than producing elegant images. It will mean a development of tools to define for instance connection details between different materials. Models have to be created with professional knowledge to avoid mistakes by automation.

Educating institutions usually work with simplifications and the real benefit of object based design might therefore not be so obvious to them. And so far the computerization has created a rather low degree of expectation on what is really usable in the real world. Software developers and computer enthusiasts have from time to time too early made promises and announced that "everything is working". On the other hand if education is not ahead of practice there is a risk that the students will be unemployable when they enter professional life.