BIM on the construction site: Generating on demand, task specific drawings in the site office

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ABSTRACT: Building Information Modeling is accepted as the new technology for design, engineering and collaboration AEC projects. There is a group of people that has specific needs on the BIM data: the construction workers. At this moment drawings are created from a BIM model at a specific moment in the whole building process. The information on the drawings is the same as the information that was put on before BIM technology came around. It contains general information for lots of different workers and craftsmen. The question remains if the information on the drawing still is the information that is needed on the construction site. With a raising complexity and fragmentation of experts on a construction site, most drawings are not specific enough for specialized tasks. BIM creates the opportunity to dynamically generate drawings fit for a specific task or purpose. This can be done with little effort because the generating of drawings from a BIM is common technology these days. Using this approach anyone in the site office can generate a drawing on demand, fit for a specific task. The drawing only has to contain the information for that one task. There is no other information that distracts the workers. The drawings can be printed on a manageable A3 piece of paper. Everything to instruct the site worker or craftsmen for the task at hand. The hypotheses is that, by giving a worker task specific information he is better informed, and less distracted by other information, improving the quality of his work and reducing the change of failure.
Results of the research show that this approach creates a very good communication tool between the site office manager and construction workers. More and more specialized workers attend a construction site for only a short moment of time, to perform only one specific task. They are not aware of the context of the whole project. Giving them on demand information on paper improves the efficiency of their work on site. The collaboration between site workers and the site office manager is the key factor in the approach. The information has to be available on time for the construction workers.

1 INTRODUCTION

Building Information Modeling is accepted as the new technology for design, engineering and collaboration AEC projects. The focus of BIM research has shifted slightly to the Operate and Maintain sector. There is a lot of research conducted on how facility managers prefer to handle the BIM data. There is however another group of people that has specific needs on the BIM data: the construction workers. Although there is a technology push starting to put augmented reality on the construction site, most of the construction workers still prefer and need paper drawings. At this moment drawings are created from a BIM model at a specific moment in the whole building process. The information on the drawings is the same as the information that was put on before BIM technology came around. It contains general information for lots of different workers and craftsmen. The generation of these drawings from a BIM is very optimized and automated. The question remains if the information on the drawing still is the information that is needed on the construction site. With a raising complexity and fragmentation of experts on a construction site, most drawings are not specific enough for specialized tasks.
BIM creates the opportunity to dynamically generate drawings fit for a specific task or purpose. This can be done with little effort because the generating of drawings from a BIM is common technology these days.

The research was conducted with the same site office manager for all construction projects.

2 PROBLEM STATEMENT

At this moment generally drawings are created from a BIM model at a specific moment in the whole building process. The information on the drawings is the same as the information that was put on before

BIM technology came around. It contains general information for lots of different workers and craftsmen. The generation of these drawings from a BIM is very optimized and automated. The question remains if the information on the drawing still is the information that is needed on the construction site. With a raising complexity and fragmentation of experts on a construction site, most drawings are not specific enough for specialized tasks.

3 SOLUTION APPROACH

BIM creates the opportunity to dynamically generate drawings fit for a specific task or purpose. This can be done with little effort because the generating of drawings from a BIM is common technology these days.

Using this approach anyone in the site office can generate a drawings on demand, fit for a specific task. The drawing only has to contain the information for that one task. There is no other information that distracts the workers. The drawings can be printed on a manageable A3 piece of paper. With a normal A3 printer the drawings can be printed in the site office on site. It is just as easy to print one or more 3D views with it on another A3 piece of paper. Everything to instruct the site worker or craftsmen for the task at hand. The hypotheses is that, by giving a worker task specific information he is better informed, and less distracted by other information, improving the quality of his work and reducing the change of failure.
This approach was implemented on several construction sites in the Netherlands in the last years. Several of these pilot projects where analyzed and evaluated.

4 CASE STUDIES

Three case studies were done during this research. In 2010-2011 an office building of about 1900m² was conducted. During this project experiments with on the fly generation of drawings was done.

During 2011-2012 a residential building of about 1700m² was conducted. During this project parts of the BIM model were used to generate drawings.

During the construction of a 2012-2013 health center of about 550m² the BIM model was the center of the process. Everything on site was done based on the models.

4.1 *Methodology*

At the construction site, no traditional drawings were used. Information came from BIM, including geometry, using IFC. There were no traditional building specifications, only the model 'As Ordered' and program requirements, directed by the project team.
The site officer created 2D drawings from the models for a specific (complex) task that was at hand. Important to state is that there were multiple BIM aspect models during the project (Berlo et al 2012). The site officer gathered all information from multiple aspect models and non-BIM data sources to create the information for the workers. These drawings had 2D information on it, but also one or more 3D views and sometimes additional non-geometric data.

Figure 1. Impression of the site officers desk. This site worker comes in to get an impression of the 3D model. Notice the drawings cabinet being almost empty. No large drawings were used in this project.

5 EXAMPLES

Some examples are presented in this chapter. In these examples we try to address the research questions: *What kind of information has to be on a drawing generated from BIM*?; *Who can generate these drawings on site*?; *Does this approach improve the construction quality and reduce failure costs on site*?

5.1 *Mounting frame for window frames*

To fulfil the task of mounting frames, specific information is needed. To create an information layout, several models are needed. In this example, information is gathered from construction, ground level floor, concrete walls and offcourse the model with mounting frames. When these models are visible in the design tool (ArchiCAD), information can be added on the layout. Dimensions from the end of the concrete wall to the start of the framing can be added, as well as dimensions from the concrete floor or foundation. The needed information is gathered from several models and added to the information

layout, which is used by workers on the construction site.

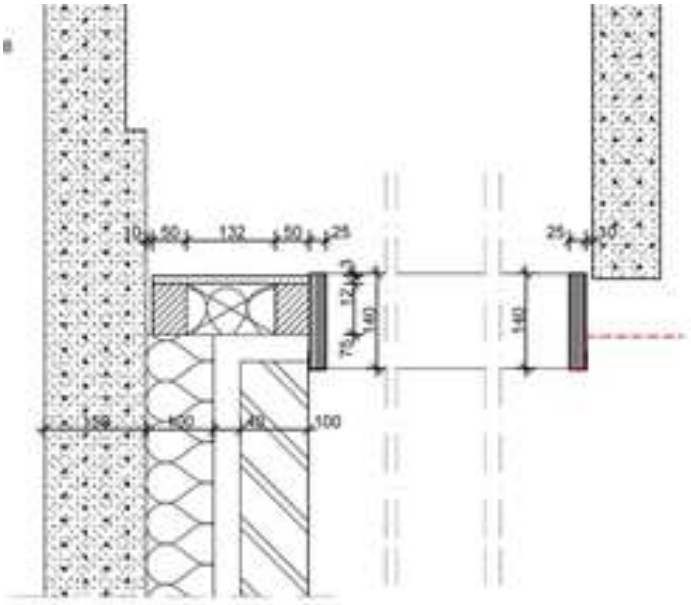

Figure 2. The A3 paper the construction workers got to do their job.

5.2 *Deviation pile foundation*

Because the piles used in the foundation were not positioned correctly, the construction engineer had to take measures. The foundation beams would be partially widened. This information was translated in a model. This new model was used at the construction site to fulfill the need for information from construction workers. The corner of the ground floor was a new dimension on a drawing, used when positioning the floor (in comparison with the other corner). The widening also had effect on the positioning of cables through and under the foundation beam. The presented information on site also included a view of the exact slab that was used, together with new dimensions from the foundation beam.
Traditionally this information would be given on separate drawing and papers. When the effect is not serious, the renewed drawing would be presented when construction is already complete (revision). This increases the possibilities of mistakes being made at the construction site, because information is not up to date.

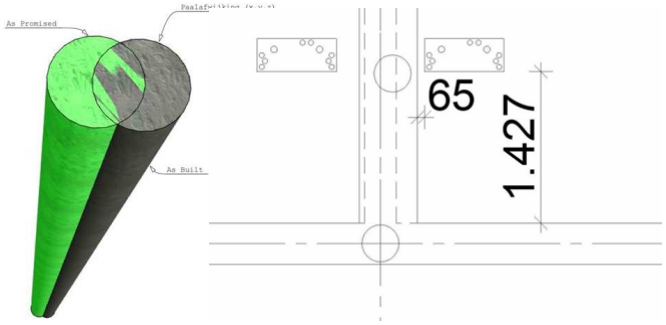

Figure 3. A deviation in the foundation was altered in the BIM to generate new drawings on site.

5.3 *Façade carrier*

A steel construction was used as façade carrier. The structure was related to the As Built concrete walls. This relation was presented on paper by direction of construction workers. By asking questions like ‘what information do you want, when positioning this structure? Upper side of the diagonal or underside, in vertical dimension?’ Vertical dimensions on site were determent by laser. Horizontal dimensions by measurement from concrete walls. Before the actual positioning started, a quick view of the model gave the construction workers insights about strategy. At the workplace information was used on paper. This was the information they asked for.

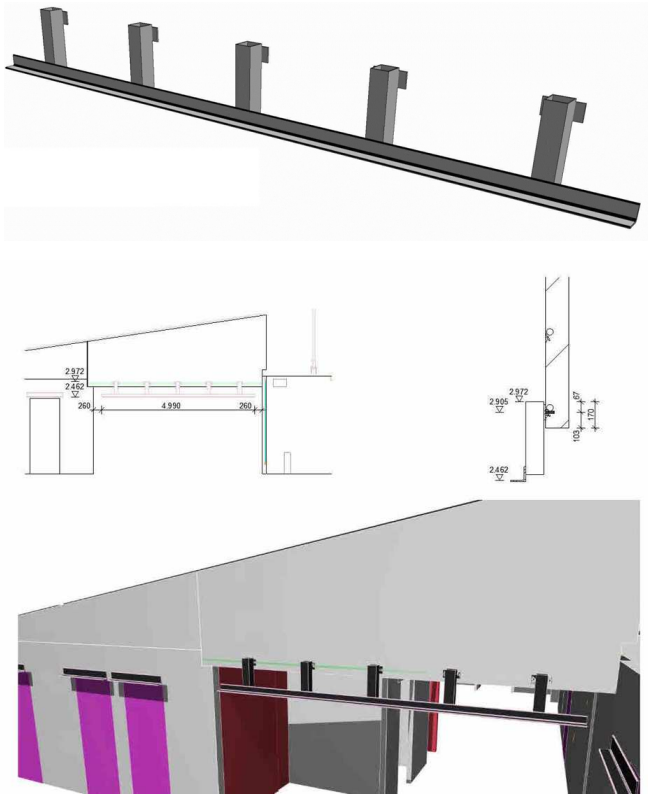

Figure 4: The façade carrier

Traditionally the information would be gathered from different drawings. The more complex and more relations, the more drawings. These drawing may not all be carried to the workplace, but someone has studied de relations between them all. There could be a good drawing of the design detail but when the structure changes, the drawing should change too. Handmade marks are a practical solution in traditional matter. At the construction site there is no time to wait for new drawings to arrive.

5.4 *Ventilation ducts through ground floor*

The positioning of ventilation ducts was presented in relation with the as built ground floor and foundation beams. In the model of the floor, the positioning of bearings was visible. The ventilation ducts were positioned between these bearings. Because the con-

struction workers asked for dimensions from the foundation, this relation was presented on the drawings created on site.
Traditionally a big crowbar was used to punch at Styrofoam sides of the floor in search of a good position, somewhere around the place in the front view, as directed by an architect in relation to masonry. The problem would be the masonry, because this is not present when positioning the ducts.

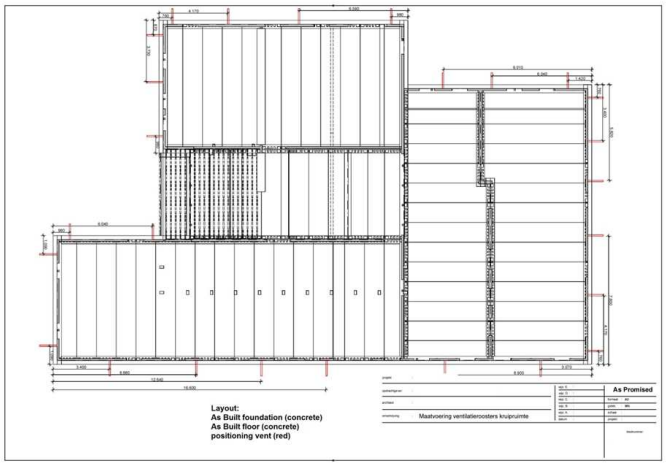

Figure 5: ventilation ducts in the floorplan

5.5 *Casing through foundation*

To create casings through the foundation of the project, information from different subcontractors and advisors was used. Therefore information about the foundation was gathered along with information from installations, and put on a layout so workers could fulfill the specific task. Dimensions where gathered from the relations between installation and foundation, resulting in a layout of information on paper, which could be used on site to fulfill the task. Because the pile foundation had a deviation, the 'as built' model of the pile foundation was updated as well as the model of the beam foundation ('as promised'), according to comments of the constructor.

5.6 *Laminated beams*

The subcontractor, which delivered the laminated beams, was able to work in BIM. He received the latest information in IFC from the project partners. His 'As Promised' model was used in a verification model (aggregated model used for clash detection). The clash with a cable tray resulted in an IFC model of the laminated beam with a hole in the middle, also by direction of the construction engineer.
To perform the task of positioning of the laminated beam, the latest information was printed on paper. This included walls 'As Built' and information from the sub-contractor, his model and additional directions for the purpose of the task. The view on the layout gave a quick impression. Detailed information about connections helped during the assembly.

Traditionally the information needed would be brought to the site office. It would have been multiple drawings and additional information. Handmade marks would combine information from different drawings. The time spend on site, is much more than the time that was needed to bring together the needed information.

5.7 *Experimental*

During the pilots some experimental operations were put to the test.
For example there was an experiment with adding non-task specific information on paper. Information about the weather conditions for example, or events related to a specific date in time. Also information from suppliers, like a telephone number.
Other experiments were about non-geometric (but task specific) information on drawings, like information about prescription or regulations. In one example the maximum screw spacing when using HPL cladding was added from the supplier.

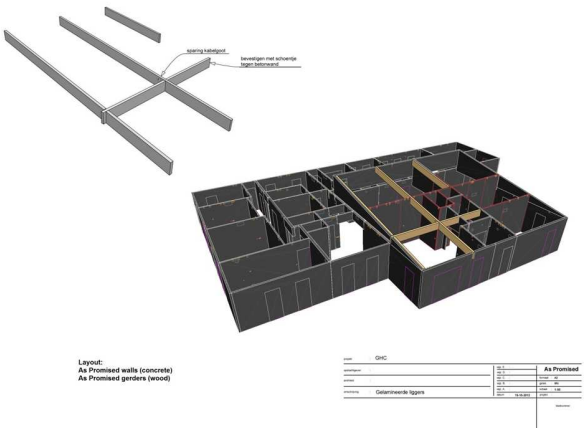

Figure 6: experimenting with source data on drawings.

To validate the source data of the drawings, there were experiments with model names and filenames, to apply at drawings. Most favorite was the filename including phase, aspect, definition and date. This made it possible to trace the origin and freshness of a drawing.

6 OBSERVATIONS

Results of the research show that this approach creates a very good communication tool between the site office manager and construction workers. More and more specialized workers attend a construction site for only a short moment of time, to perform only one specific task. They are not aware of the context of the whole project. Giving them on demand information on paper improves the efficiency of their work on site.
The collaboration between site workers and the site office manager is the key factor in these examples. The information has to be available on time for the

construction workers. To fully profit from this approach anyone on the site with proper competences can generate the drawings on demand. For example: after this pilot other projects have used BIM modelers on site to generate the drawings.
The pilot projects show that it is not about extracting information from a BIM, but about giving site workers task specific information. Combining information from several sources, and presenting it without noise of non valuable information, is the key factor in this approach. For some tasks it is necessary that non-BIM information is added to the drawings, but for many tasks the needed information could be retrieved from BIM.

In short these are the observations from site workers and the site officer:

Advantages:

- Extra info besides BIM (for example about assembly instructions, construction methodology and strategy, manufacturers information, etc.)
- Task specific information
- No distractions
- No searching for information on a drawing
- Manageable drawings (A3)
- Replaceable (expendable) drawings
- Less issues on site during construction (this is the sentiment; not backed by research results).
- It is fun

Disadvantages:

- Every morning (or at least for every task) a drawing has to be made.
- Very strict planning (lean)
- When site officer is sick, who replaces him?

7 CONCLUSIONS

A tentative conclusion can be drawn that this approach is very effective for on site communication between site workers and the site officer. Especially site workers that are only on site for a short time, to perform a specific task (subcontractors) report this approach as a unique way to quickly get an overview of the project and the specific task at hand. The collaboration between site workers and the site office manager is the key factor in the approach. The information has to be available on time for the construction workers.
The generated drawings can still have too little information. This can be fixed quickly, but does not provide the effectiveness that can be achieved. Obviously the success factor is in the hands of the person that generates the drawings.
The kind of information that has to be on a task specific drawing can be more than just information from a BIM. In these pilots the site officer had an overall overview of the project so he could filter the information and present it without noise to the construction workers. In the pilots this didn't lead to problems, but we can imagine that this is a risk factor for the approach (although some site officers claim that this is also the situation without this concept).
The actors involved in the pilots believe that anyone with insight in the problems on site can create the drawings. This is also perceived as an advantage: on site problems are being coordinated on site.
There seems to be an overall sentiment that this approach improves the efficiency on site; the effectiveness of site workers and the resulting quality of the construction.

8 DISCUSSION

The presented approach is only one methodology for provide task specific information on site. Other approaches are the use of a smart board, tablets or even Augmented reality (Helmholt et al 2009). The research presented in this paper was based on pilots and interviews. Therefore a comparison between these approaches is not possible and conclusions about comparison cannot be made.

Some site officers think that this approach to information providence on a construction site keeps site workers dumb. We cannot conclude anything like that based on this case study controlled research.

For good comparison the same site officer was put on the job for all pilots. This could give a biased opinion about the approach. The conclusions about construction efficiency, effectiveness and resulting quality are all based on the opinion of the involved actors. Further (double blind) comparison research has to be conducted to claim this conclusion.

9 FUTURE RESEARCH

Obviously more testing has to be done to validate the conclusions. Testing on different construction sites with different site officers has to be done.

Another interesting approach is to start research about the Automatic generation of task specific drawings. This solution will make this approach more independable from the competence of the site officers, and might even improve quality. The presented concept is based on combining fragmented data from BIM aspect models and non-BIM data sources into a single view for construction workers. Another approach is to put all data into a single data

format (Goedert et al 2008). This could make automatic generation of task specific drawings easier.

Still unclear is what (extra) competences a site office manager needs to have to fully apply this approach. Obviously the general overview of the project has to be there, but this is no different from traditional projects.

These pilots are typical Dutch pilots. The Dutch construction industry is a fragmented industry where several sub-contractors perform specific tasks over a short period of time. It is yet to be researched if this approach is useful and valuable in other countries.

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