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BIM ON THE CONSTRUCTION SITE: PROVIDING HIDDEN INFORMATION ON TASK SPECIFIC DRAWINGS

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SUMMARY: *Building Information Modelling (BIM) is accepted as the new technology for design, engineering and collaboration AEC projects. BIM can be seen as a collection of objects, properties and relations. Many parties in the construction process use the data in their benefit. There is a group of people that has very specific needs on using 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. In a BIM data collection much more information is available, but this information stays hidden for construction workers on site. With a raising complexity and fragmentation of experts on a construction site, most drawings don't seem to provide enough information, and are not specific enough for specialized tasks. This paper provides a concept, tested in practice, to dynamically generate drawings fit for a specific task or purpose. The main purpose of this concept is to provide site workers with all the information they need for the task, but nothing more. Using this approach anyone in the site office can generate a drawing on demand, fit for a specific task. The information on the drawings may contain specific information that comes from BIM data (or any other data source) that is traditionally not available on a drawing. 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, including context they need, 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.

KEYWORDS: *BIM, building information modelling, construction site, drawings, hidden info, task specific.*

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1. INTRODUCTION

Building Information Modelling (BIM) 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 crafts-men. 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 datasets hold much more information compared to traditional drawings. This means much more information is available during the construction process, but it seems to be hidden from site workers. This paper provides a concept to provide site workers with information that could benefit them in their works, but is traditionally not provided to them.

Providing 'hidden' BIM information could be done with Augmented Reality (Helmholt et al, 2009), Tablet, mobile apps, or any other gadget. To connect with the current perception and experiences of site workers, we decide to provide them the information on paper. BIM software 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 drawings are created 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 was used. It contains general information for lots of different workers and crafts-men. BIM holds much more information than the small part that is put on drawings. This additional information can have potential value for site workers.

The problem statement of this research is that site workers don't have access to this information that is somewhere available in a BIM dataset. To them the information is 'hidden'.

During this research the aim is to provide site workers with the information that is normally hidden to them. To connect with the perception of the site workers, we aim to provide that information explicit and on a piece of paper.

3. SOLUTION APPROACH

More and more software provides an opportunity to dynamically generate extracts (fit for a specific task or purpose) from a BIM dataset. This can be done with little effort because the generating of extracts from a BIM is common technology these days. Extracts can be drawings, but also tables of data, coloured overviews, whatever.

Using this approach someone with the right competences, can on the site generate extracts on demand, fit for a specific task, from the complete dataset of BIM information. The extract only has to contain the information for a specific task at hand. There is no other information that distracts the workers. Most site workers (including the site office manager) call these extracts 'drawings' although most of the time, the information on the extract only contains small parts that look like traditional drawings. More on that in the examples later. The extracts can be printed on a manageable A3 piece of paper. With a normal A3 printer the extracts ('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 has two parts:

- 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 chance of failure.
- By providing the site worker with information that is not available to him in a more traditional process (with drawings that are created weeks or months and without a specific goal in mind), the worker can work more effective an efficient improving the quality of his work and reducing the chance of failure.

This approach was implemented on several construction sites in the Netherlands in the last years. Several of these pilot projects where analysed and evaluated.

During this research the question about automating the generation of the extracts comes to mind very fast. This research has a strong focus om finding the practical implications of this solution approach on site. Therefore the automation of the extracts is not in focus for this research.

4. CASE STUDIES

Four 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 centre of about 550m² the BIM model was the centre of the process. Everything on site was done based on the models.

During the 2014 construction of a multi purpose building (offices, apartments, theatre), site workers got advanced information on paper that was normally hidden from them and only available in BIM.

4.1 Methodology

At the construction site, no traditional drawings were used. Most information came from BIM data, including geometry, using the IFC data standard. 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 IFC data for a specific (complex) task that was at hand. Important to state is that there were multiple IFC 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 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 available for site workers?
- Who is capable of collecting this information and providing it (on paper) 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, off course, the IFC 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.

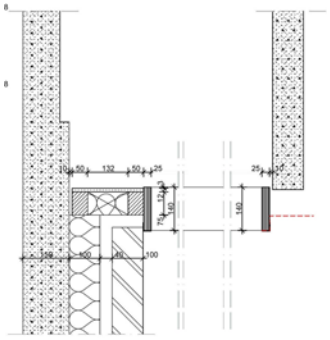

Figure 2. The A3 paper the construction workers got to do their job.

5.2 Deviation pile foundation

Because the piles used in the foundation were not positioned correctly, the construction engineer had to take action. The foundation beams would be partially widened. This information was adapted in an IFC model. This new model was used at the construction site to fulfil 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.

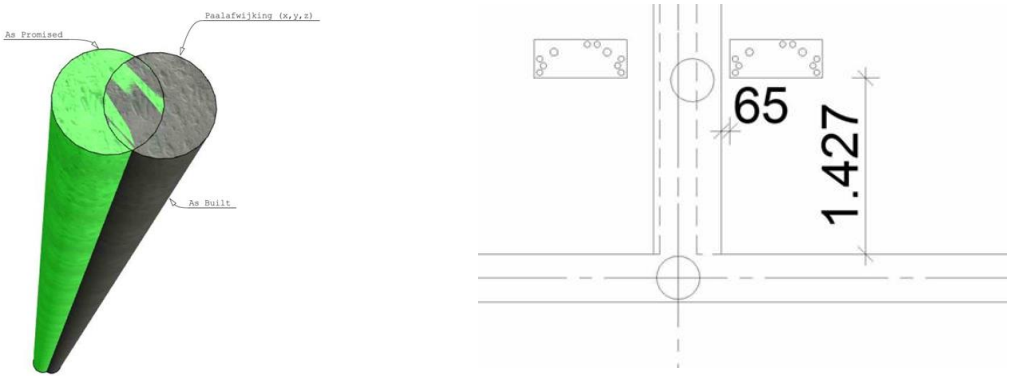

Figure 3. A deviation in the foundation was altered in the BIM to generate new drawings on site.

5.3 Façade carrier

A steel construction was used as façade carrier. The structure was related to the 'As Build' 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.

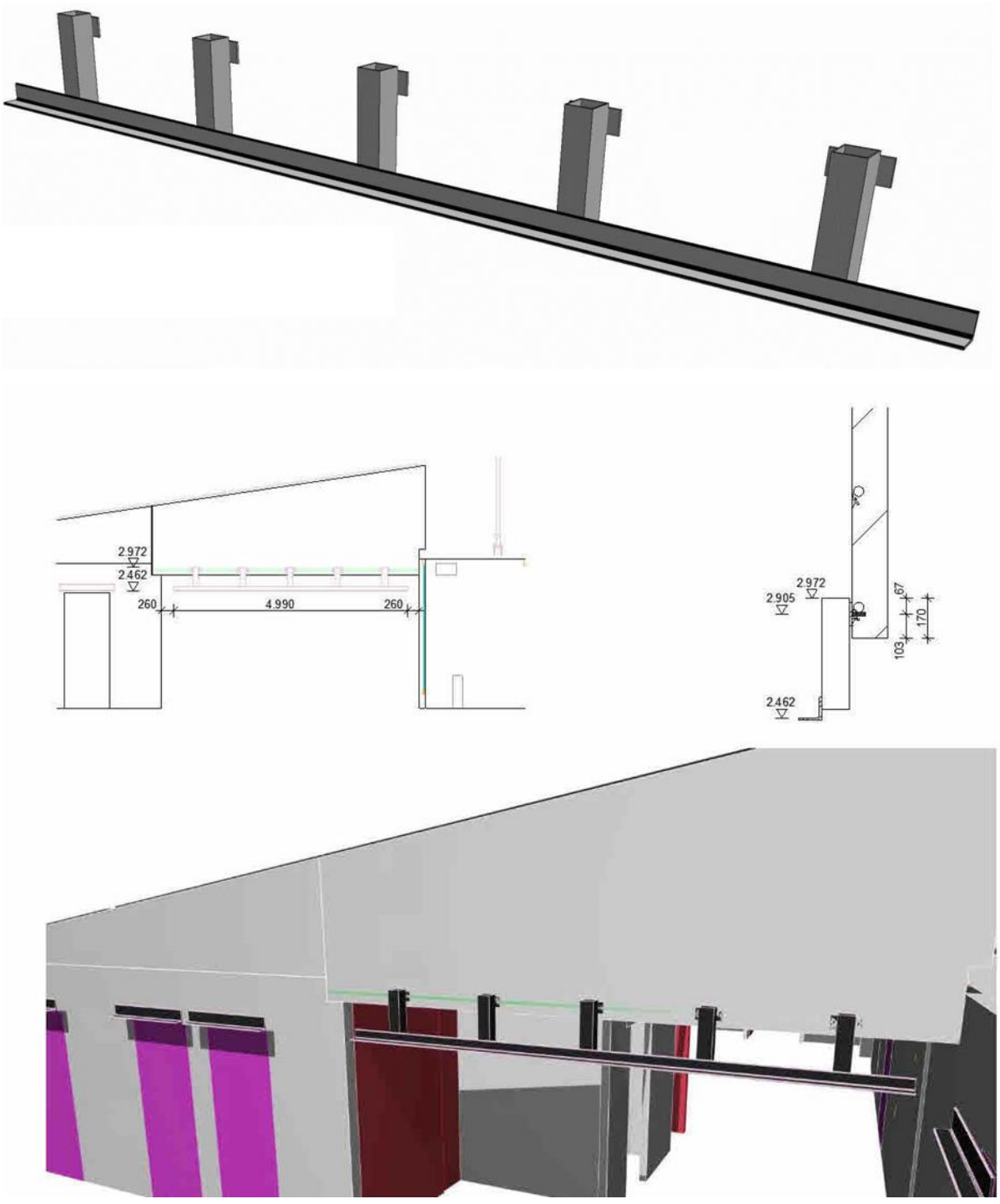

Figure 4: The façade carrier

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..

5.4 Ventilation ducts through ground floor

The positioning of ventilation ducts was presented in relation with the 'as build' 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 construction workers asked for dimensions from the foundation, this relation was presented on the drawings created on site.

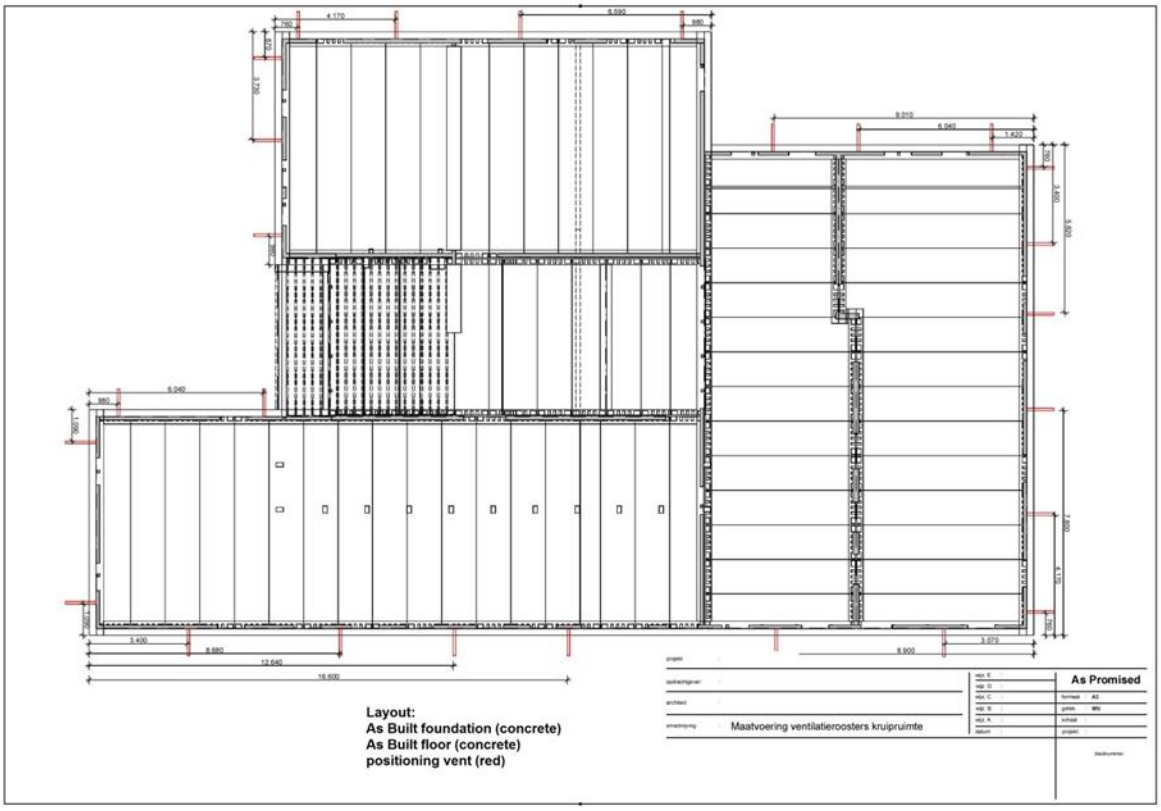

Figure 5: Ventilation ducts in the floorplan

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.

5.5 Casing through foundation

To create casings through the foundation of the project, information from different subcontractors and advisors was provided. Information about the foundation was gathered along with information from installations, and put on a layout so workers could fulfil 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 fulfil the task. Because the pile foundation had a deviation, the 'as build' model of the pile foundation was updated as well as the model of the beam foundation ('as planned'), 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 Planned’ 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 Build’ 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 Using colours to provide 4D information

Another example on how to provide information that is normally hidden for site workers, it the use of colours to provide information about construction sequences.

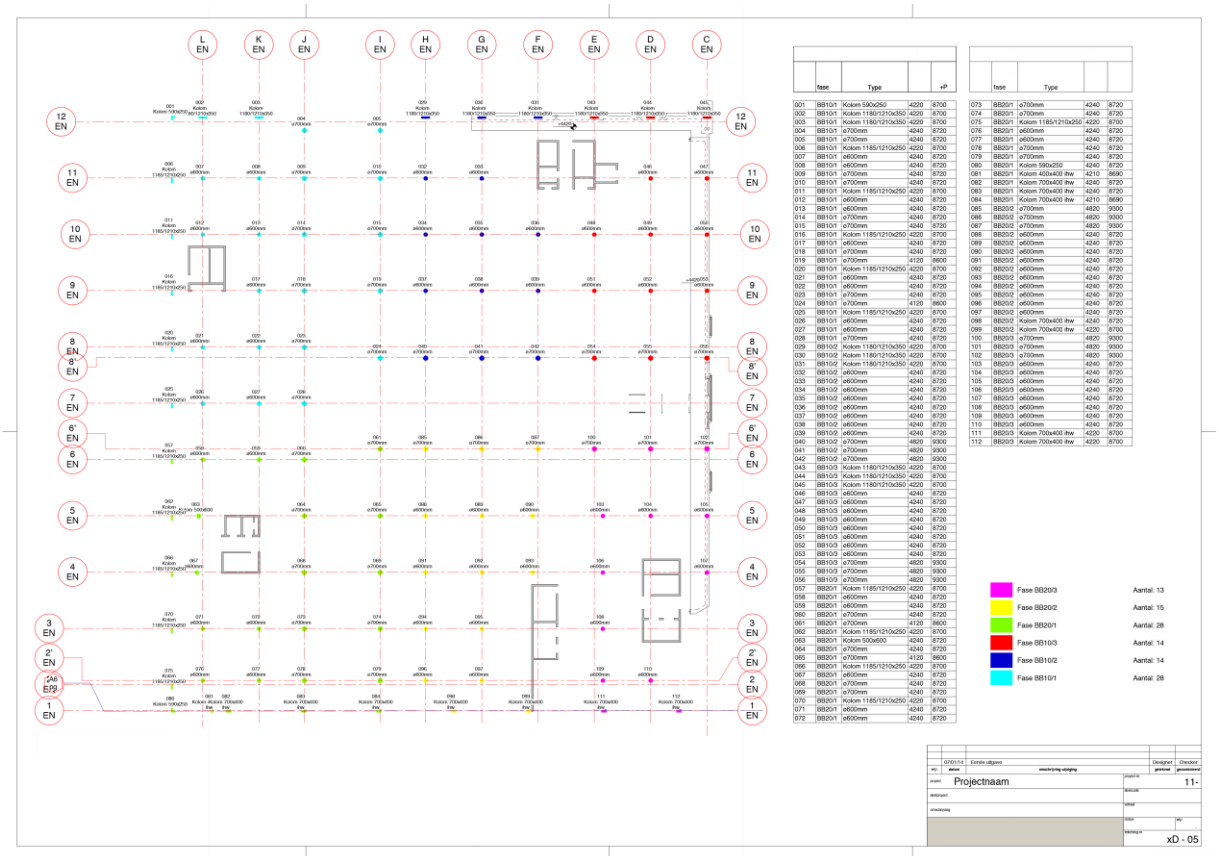

Figure 6: Example of a drawing with colour coded columns. The colours represent the building phase which provides the site workers with information about construction sequence (4D).

This example is about the construction of concrete columns. On any traditional drawing the columns are presented on a grid. In this case we also used a 2D drawing with a grid. Therefore we created a layout that can be printed (A3) for use at the construction site. Additionally, six different colours were used to show the construction sequence and phase. A unique number helps communicating about a specific column and reflects the number on the casing, presented by the supplier. The resulting drawing is showing grids and columns in

different colours. Every column has a tag with a number and diameter. This number is also represented in the schedule. The schedule helps construction workers to plan the positioning of the columns.

The amount of information could be less, when zooming to actual production per day. On the other hand is this a view on small paper (A3) that can be used in multiple tasks, changing only the content, not the layout. For example when creating the reinforced strips, floors, bearing walls and non-bearing walls, interior finishing, et cetera.

The information provided to the site workers on paper, is normally only available as a combination of properties on objects in a BIM, information in the schedule, codes from the supplier, phase, type, tube length and pouring height. In this use-case all these data sources, are made available for the site workers in one handy overview, printed on a colour A3 piece of paper.

5.8 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.

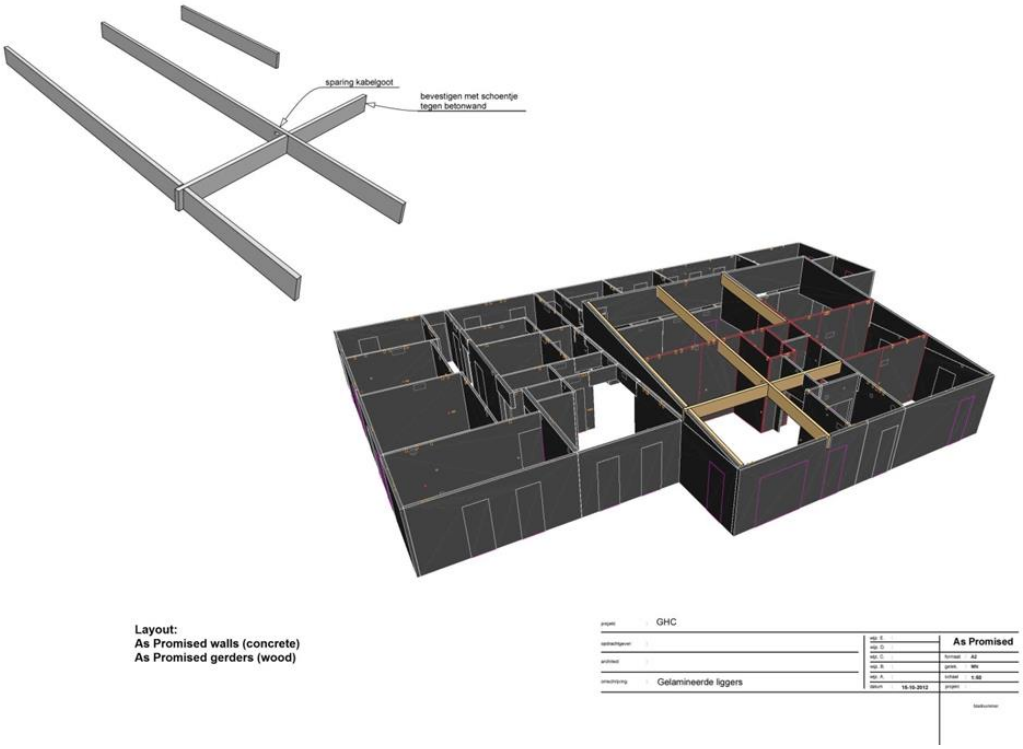

Figure 7: Experimenting with source data on drawings.

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

During the use-case of example 5.7 (using colours to provide 4D information) we also did experiments with automatic generation of the drawings. In the modelling software, a standard ‘modelview’ is created to view a subset of the data. Whenever the data changes or updates, the drawing will also change, which makes it a dynamic view. With this approach, drawings can be generated ‘just in time’, using current model information, automatically added with task specific information.

6. OBSERVATIONS

Results of the research show that the approach to provide site workers with information that is normally hidden from them is very valuable and could improve the quality of the building.

The chosen concept of using drawings on A3 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 provide the information on demand (i.e.generate the drawings on demand). For example: after these pilots other projects have used BIM modellers on site to generate the drawings.

The pilot projects show that it is not about creating drawings, but about providing site workers enough valuable and specific information. Combining information from several sources that is normally not available for site workers, 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 provided, but for many tasks the needed information could be retrieved from a BIM.

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

Advantages:

- Providing information that is normally hidden or not available to site workers
- 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
- It is about providing 'hidden' information. The information still has to be somewhere and someone has to be able to find it
- Very strict planning (lean)

7. CONCLUSIONS

A 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 on site, but does not generate the full effectiveness that could be achieved. On the other hand the provided information is often already more than traditionally. So although it is still not always complete, it is already better than traditionally.

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).

An important conclusion of this work is that there is a crucial role for the person generating the drawings: he is the one gathering all available information and presenting it in the best possible way. Using Augmented reality, tables, Google Glass, or any other gadget, doesn't solve the problem of searching for the correct information. Information is available thanks to the use of the BIM concept, but it still remains hidden for site workers without the needed competence to handle the technology. Providing information that is available, but 'hidden' for site workers is they key to the success of this concept. Not the medium on which the information is provided. The actors involved in the pilots believe that anyone with insight in the problems on site, ánd proper knowledge of BIM technology and tools, can provide the information to site workers in a way that it is effective.

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 to provide site workers with task specific information that is normally hidden from them. The research presented in this paper was based on pilots and interviews. Therefore a comparison between other 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. Another interesting approach is to continue research about the automatic gathering of information and generation of task specific drawings. This solution could make this approach more undependable from the competence of the site officers. 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 drawings easier.

Still unclear is if a site office manager needs to have additional competences to use this approach. Obviously the general overview of the project has to be there, but this is no different from traditional projects. Also an affinity with BIM tools and technology seems to make sense.

10. REFERENCES

Berlo, L.A.H.M. van & Beetz, J & Bos, P & Hendriks, H & Tongeren, R.C.J. van. (2012). Collaborative engineering with IFC: new insights and technology. Proceedings of the 9th European Conference on Product and Process Modelling 2012 ECPPM, Reykjavik, 25-27 July.

Goedert, J. & Meadati, P. (2008). Integrating Construction Process Documentation into Building Information Modeling. J. Constr. Eng. Manage. 134(7), 509–516.

Helmholt, K.A. & Hoekstra, W & Berlo, L.A.H.M. van. (2009). C2B: Augmented reality on the construction site. Proceedings of the 9th International Conference on Construction Applications of Virtual Reality. Sydney, Australia, 5-6 November

Laine, E. & Alhava, O. & Kiviniemi, A. (2014). Improving Built-In Quality by BIM Based Visual Management. Proceedings IGLC-22, Oslo, Norway