The automation of the process of updating the curing time activity in 4D schedule

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Abstract –

In todays practice, we encounter different approaches to solving the problem of planning a curing time for wet processes. The article focuses on concrete processes where the length of the curing time needed for formwork removal is dependent on numerous factors. By using sensors that monitor the internal temperature in the concrete, we can determine the time of stripping of the formwork more precisely. The aim of this article is to describe the process of possible automation of the update in the duration of the technological break (curing time) and the integration of this data into the BIM model. The proposed process will be used to solve the active link to the update of the formwork removal activity in 4D simulation of the construction.

Keywords –

BIM, 4D simulation, Formwork removal

1 Introduction

The effectiveness of cooperation between construction participants can be clearly increased by sharing information from the BIM model. However, it is essential to ensure the sharing of digital files, not only between design applications but across all stages of the building's life cycle. In the past, it was almost impossible to open and edit files in a different environment than where they were created. Such an approach has limited cooperation and also freedom in choosing software. Today the situation is different.

Updating the 4D models, if done manually, is time-consuming and labour intensive, which discourages their use among industry practitioners (Lopez et al. 2015). There is a need for solutions that automatically incorporate the detected progress data into 4D BIMs and update the schedule and tasks associated with 3D model objects (Chen et al. 2015; Kim et al. 2010).

According to our study, there is potential in optimization of the process of updating the construction schedule with partial automation. Such an example is formwork removal activity that could be updated without the need of manual input. This can lead to savings related to cost and time and providing direct source of information in order to make a right decision.

2 Building Information Modelling

2.1 Process

The goal of BIM is not to create a model itself, but to gain complete, reliable, accessible and easily exchangeable information to anyone who might need it throughout the whole life cycle of the building.

The data rich information model, today interpreted as BIM model basically consists of three parts. We can characterize it as a combination of graphic and non-graphic data and any documents related to a construction project according the definition of English standard PAS1192-2. In some definitions, metadata is included as part of the information model except for the three above mentioned components. For BIM to be complete, we need all this information for each element, object, product, material or system that is included in the project. The detail of this information can be referred to as the Level of Definition, which includes the level of detail and level of information, and therefore describes the specification of the information model on a graphical and non-graphic base.

Graphic information can be 2D or 3D and are expressed in shape and layout in space. This information is basically a 3D model, its graphic, a geometric representation (in native or exchange format) that provides visual orientation, location and context, defines relationships between rooms, spaces, and other elements in the model. Although it is estimated that the graphical representation, respectively. A 3D model that contains geometry only represents only 5% of the project information, this part of the model is necessary for computer coordination (for example, for collision detection) and serves to link and determine relationships with the systems. Simplified, the 3D object serves as a container for some non-graphical information or parameter information and potentially provides a link to other information in other formats and placements.

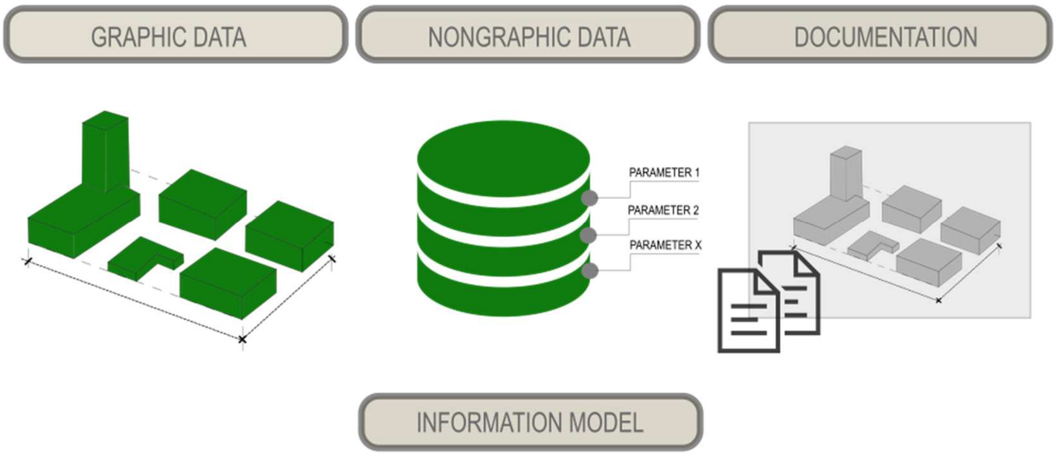

Figure 1 Building Information Model

The Level of Detail (LOD), i.e. the detail of its geometric representation, can define the relevant standard or is defined in the BIM (BIM Execution Plan) and expresses the required detail in each phase of the project.

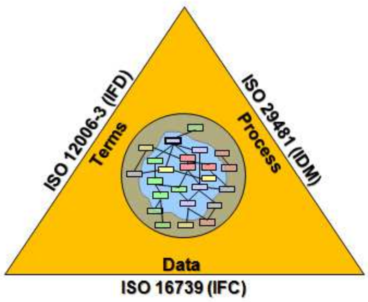

Figure 2 Basic schema of standards

2.2 Interoperability

Another fundamental prerequisite of BIM process is interoperability. Individual software applications store information primarily in their native formats, which is a major challenge in the digital world of the construction industry. In order to make information available to all participants throughout the life cycle, software applications must enable and secure reliable data exchange.

Interoperability refers to the property of a product or system communicating and working with other products or systems without any limitations. It could also be said that interoperability is the ability of a system or product to work with other systems or products without the need for particular effort on the part of the user. It is true that interoperable systems are capable of communicating and exchanging information to avoid uncontrollable modification and loss.

IFC (Industry Foundation Classes) file type – a neutral data format used to describe, exchange and share information between stakeholders and various software.

There are various methods, software systems and information, respectively. communication technologies that deal with effective data exchange between software applications. Basically, it can be plug-ins and programs, individual file-sharing formats created by software vendors, DXF (Data eXchange Format), or standards and open data models such as XML (Extensible Markup Language) and IFC (Industry Foundation Classes - a standardized and fully documented file format created and defined by buildingSMART).

The BIM itself is based on open cooperation and also through the IFC ensures the exchange of information from the data model between the different professions within the life cycle, thus also between different program environments. In this area, it is good to rely on the available ISO 16739 standards, which define the data themselves - IFC, ISO 29481 which defines the Information Delivery Manual (IDM) and ISO 12006-3, which define the framework for object-oriented information.

The development of IFCs is constantly advancing, and standards are tailored to the needs of the industry. In fact, the IFC1.0, IFC1.5, IFC1.5.1 and IFC2.0 have been on the market before 2000, are no longer used today. In October 2000, a stable IFC2x platform was launched, a year later updated with IFC2x-Add1. In 2003, the IFC2x2 platform was also released, which was also updated by IFC2x2-Add1. Currently, IFC2x3-TC1 - "IFC2x Edition 3 Technical Corrigendum 1" is the most used platform - it supplements version IFC2x3 from July 2007.

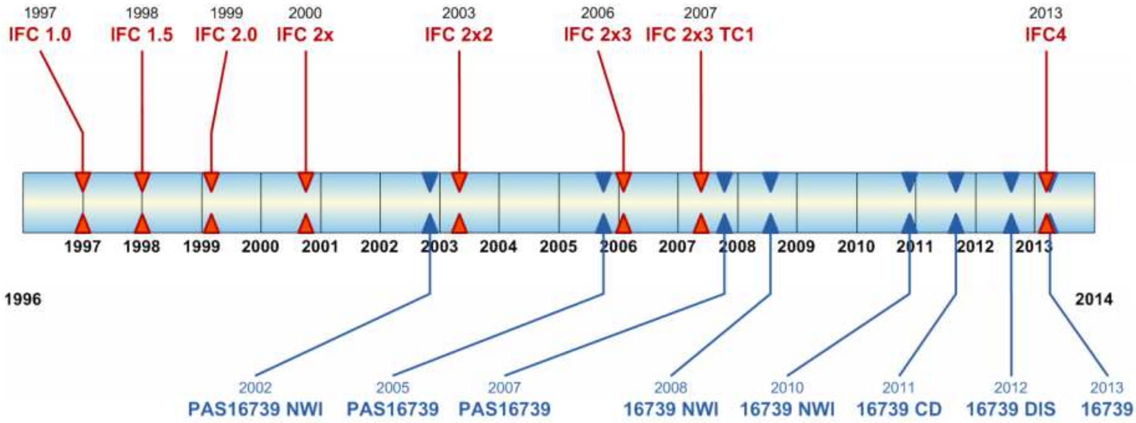

Figure 3 IFC schema, BuildingSmart

The new version, released in 2013, is the IFC4 platform (formerly IFC 2x4). IFC4 includes additional extensions related to the building, component, geometry improvements, resources, significant quality enhancement, and fully integrated ifcXML. In July 2015, IFC4 - Add 1 (Addendum 1) was released, incorporating the necessary improvements that were discovered during pilot implementations and development activities for MVD (model view definition). The next version of IFC5 is currently under preparation. The date of its issue has not yet been confirmed.

The basic schema of the most frequently used version of IFC2x3-TC1 is shown in Fig. 1. The IFC schema consists of a set of defined ways to divide information into individual classes along with the information structure that defines the objects. This structure formally specifies the attributes within the classes and defines the form in which the data will be exchanged within ISO 10303, Industrial Data Systems and Integration (Part 21, 22). The diagram is divided into three basic layers respectively. level, namely Core, Interoperability, and Domain. Platform components are shown in green.

Although definitions and structures are comprehensive, many types of information that individual users want to replace are not directly part of the IFC Model. However, it is possible to define them within the IfcPropertyResource scheme.

3 Formwork removal

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement that hardens over time. Many types of concrete are available, distinguished by the proportions of the main ingredients. The rate of hardening of concrete or the concrete strength depends on several aspects.

The curing period may depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient conditions, i.e. the temperature and relative humidity of the surrounding atmosphere. These aspects affect the formwork removal time. The process of removal of formwork in the process of casting concrete is also known as striking time. Once the concrete has achieved the initial recommended strength, to support the self-weight and any imposed loads, the shuttering is removed for further curing.

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. (Curing of Concrete, 2006).

Leaving formwork in place is often an efficient and cost-effective method of curing concrete, particularly during its early stages.

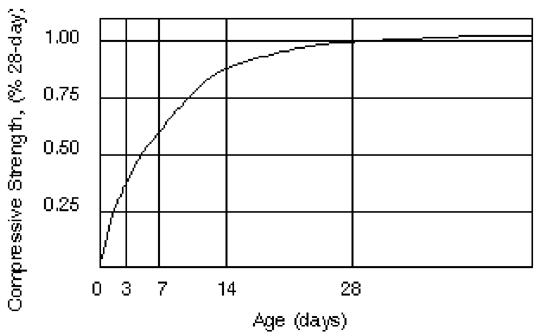

Figure 4 Typical strength-gain curve, University of Memphis

3.1 Actual approach

Stripping should be carried out only after the time when concrete has gained sufficient strength. This time represents the time lag between concrete casting and formwork removal activity.

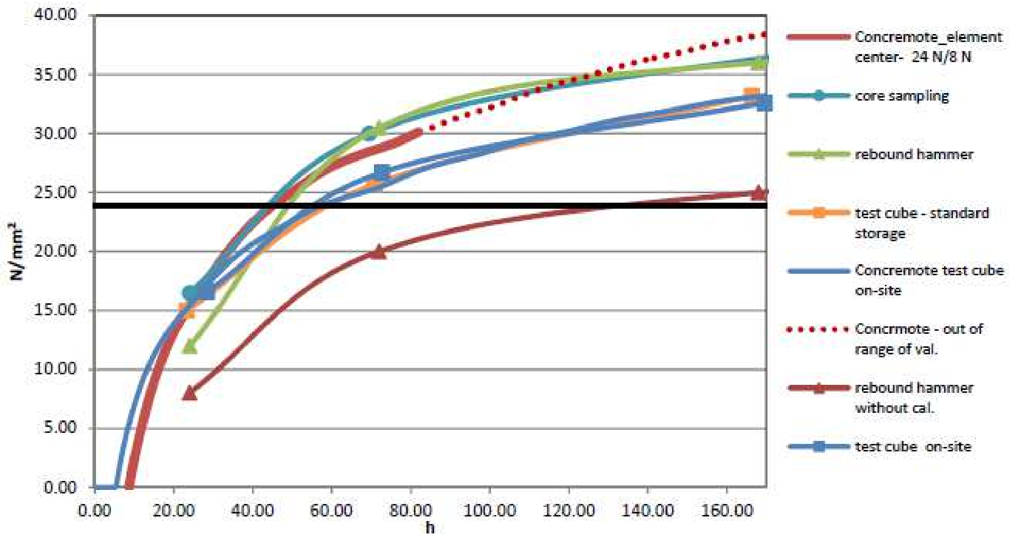

Figure 5 Compressive-strength-developments derived from different methods

"The delay after the first activity completes and before the second activity starts (wait period), is called lag and this delay is known as the Lag Time." (Project Management, book)

Throughout local construction industry, the most common understanding of the process of hardening is that it takes 28 days to cure and reach 100% of proposed strength. This is strongly connected to lag time and according to our research, this affect their estimate of duration of this task. In some cases, constructors estimate for necessary time lag until striking is possible is 28 days (form and complete set of support removal). Of course, the decision to specify date of formwork removal activity need to be confirmed via various methods.

Nowadays, companies tend to estimate striking time unsystematically, mostly relying on their previous experience or company´s internal standard. They use non-destructive tests (mostly Schmidt hammers) or obtain this information from reference samples or query the information from structural engineer.

The most common approach is using rebound-hammer to confirm the date of formwork removal. However, construction companies frequently use uncalibrated rebound-hammer and it is proven that uncalibrated rebound-hammer deliver the most inaccurate results.

In many cases, the removal of formwork process could have occurred sooner, which has a major impact on the construction process and the optimization of concrete workforce.

3.2 Sensor-based strength measurement

Non-destructive methods based on maturity calculations can be applied. There are several commercial systems on the market (Concremote, Con-Cure NEX, SmartConcrete, ...) providing non-destructive measurement of fresh concrete strength based on real-time hydration heat.

„*Most of the destructive test methods have the disadvantage of the late availability of the data. The evidence for strength is usually too late in time to make decisions regarding the building process (e.g. striking times). For optimising construction processes the real-time concrete strength methods on the basis of the calculations by de Vree are generally a promising technology.* " (Reinisch et al, 2015)

Using such a system for sensor-based strength measurement have advantages in various cases e.g.:

- decision on striking time of wall and ceiling formwork,
- information about load capacity for special type formwork for vertical concrete structures e.g. climbing formwork,
- temperature monitoring and recording due to prevent possible cracking,
- casting concrete roads to estimate cutting times for concrete joints,
- estimate aesthetic concrete maturity in order to achieve the same shade

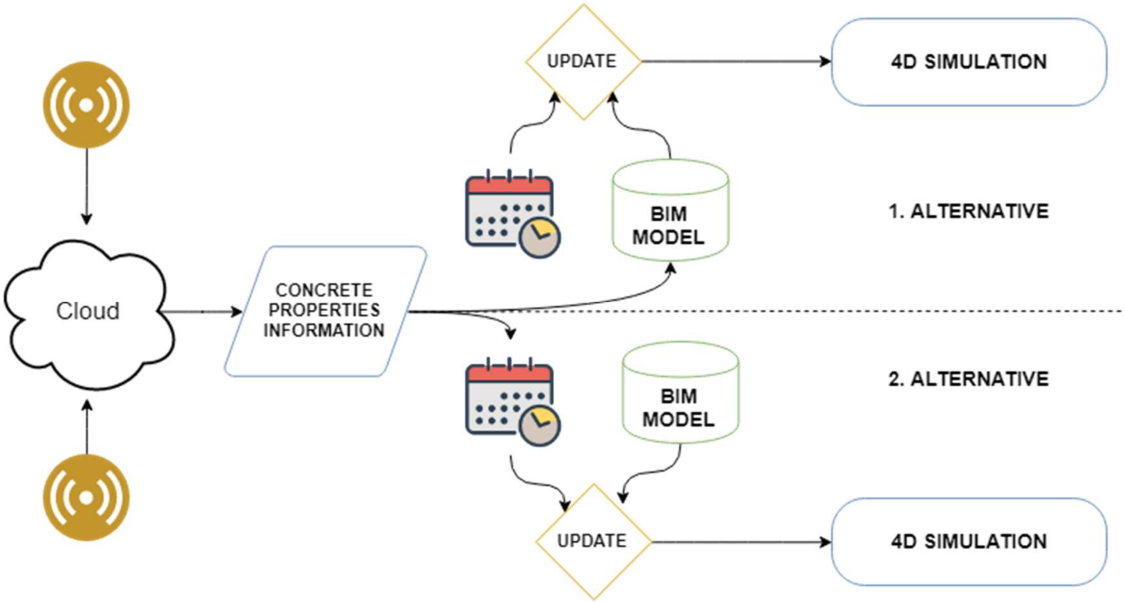

Figure 6 Flowchart diagram of proposed methodology

Primary benefit of this approach is that the measured data are collected, stored and reachable from cloud-based service. Some systems store (backup) data through local storage device e.g. SD card. Prior to use, all sensors must be calibrated to provide reliable information.

Sensors can be wired or communicate remotely and most of the built-in sensors available on the market can be used multiple times. After activation, sensor record measured temperature on predefined time span (for example each 5, 10, 30 min). Individual values are incorporated into diagram representing strength of concrete. Once the strength predefined by the customer is reached, the system automatically notifies the person responsible for the construction management via SMS or e-mail. This capability of the system to communicate autonomously in a predefined form is a base for further development of the platform for the automation of the process of updating the curing time activity in the schedule as activities related to striking task management which are its successors could be linked dynamically.

4 Proposed methodology

For the purpose of the possible automation of the process of updating the curing time activity in 4D schedule we will consider two approaches.

One approach is based on enriching 3D BIM model either by modifying IFC file or model in native format and the second is based on modifying time schedule.

4.1 Modification of 3D parametric model

Approach based on modifying BIM model either by through IFC file or native format is the platform where time information about the exact date of striking is delivered directly into model as a parameter using excel predefined template custom macro or Dynamo script. Further update of schedule by modification of the input value of model objects with assigned tasks is done in 4D scheduling software.

4.1.1 IFC based modification

Modifying IFC file allows the wider spectrum of utilized software. There are several software allowing you to edit IFC data without having access to the original model. Various authors already worked with the topic of IFC-based automation of schedule progress updating (Hamledari, et. al, 2017)

It is known that the IFC 2x3 schema specification provides a reasonable basis for the use case of model-based scheduling. The benefits of model-based scheduling are widely recognized (Porkka, Kähkönen 2007).

The aim of the rule-based linking approach is to reduce the effort for the overall set-up process by using semi-automated linking mechanisms and improve the management of data dependencies to react more efficiently on design changes. (Weise et. al, 2016)

Each IfcTask is distinguished from others by its GUID. The schedule control information, on the other hand, is modeled through subtypes of IfcControl, such as IfcScheduleTimeControl, which holds all the necessary attributes for scheduling a task such as early and late start and finish dates, duration, and float information.

For each task, the ScheduleDuration and ScheduleFinish attributes of the IfcScheduleTimeControl are updated (Hamledari et.al. 2017).

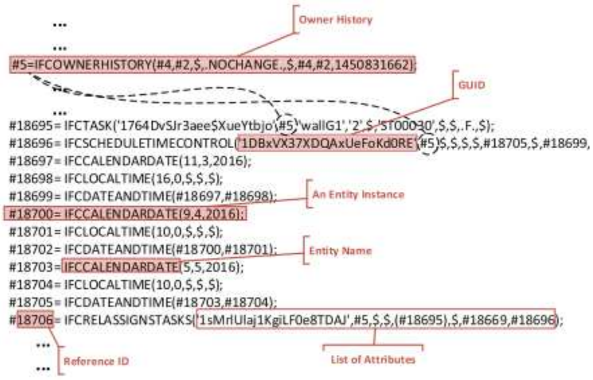

Figure 7 Parts of an IFC data model, Hamledari et.al.

Using special software, you can edit properties of IFC model. In general, you can modify property values, combine and split values and move values from one property to another. It is also possible to Enrich the model by adding new data to IFC models from external data sources (import and export of IFC2x3 and IFC4 models using the .ifc and .ifczip file formats) allowing to export the property data of BIM model into Excel.

4.1.2 Modification of model in native format

Option that we are considering is also modification of time information directly in the native format. This allows the user to work in an environment they already know and without investment into additional software. For this purpose, we are using the Navisworks to simulate construction processes. We can either manually enter information about project tasks or import schedules from many project planning software applications (MS Project, Primavera,..) and to follow with linking the elements in the model with tasks in the schedule. The procedure in Navisworks would be to link Revit model and the project plan document; followed by mapping Revit Elements to corresponding construction activities. After this Navisworks can simulate the virtual construction on Revit model using the dates provided in project plan.

In order to tag the Revit Elements with four construction dates (Planned Start Date, Planned End Date, Actual Start Date and Actual End Date).

For achieving this you can create mentioned dates as a Project Parameters (Text Type & Instance). Further you can select the individual elements as required and update fields.

4.2 Modification of time schedule

Approach based on modification of the time schedule apply when time information about the exact date of striking is delivered directly into schedule using excel predefined template and custom macro. Further update of schedule by modification of the input value of the formwork removal task is done in master scheduling software (either directly in 4D environment or in MS Project).

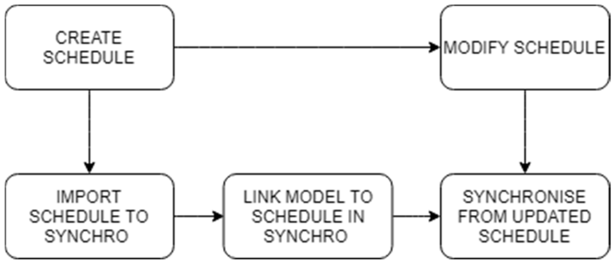

Figure 8 Synchro update process

Synchro PRO, that could be used as a tool uses XML format to Synchronise when working with MS Project. In a process of updating the schedule in 4D environment (e.g. Synchro PRO) you should skip task synchronization when synchronizing with an IFC file that contains a 3D model only, since IFC files may contain task data too.

When using Synchro PRO, it is important to be aware of various techniques of schedule modification. You can use Skip, Synchronise, Consolidate of Integrate option. For the purpose of prolongation of shorten of the lag time for striking, Consolidate of Integrate option must be used where the new schedule will be merged with previous version of schedule and depending on selection objects that were deleted in update version will be deleted (Integrate) or not (Consolidate).

5 Conclusion

Interoperability and BIM itself provides wide options for construction optimization either for reaching higher quality or mostly by using advanced techniques for partial or full automation of some processes and therefore reducing the need of manual inputs and reducing time consuming activities.

We assume that solving even partial tasks of automation of construction schedule results in better construction management.

In the local industry, the topic of formwork removal appears to be solved unsystematically. We believe that by using sensors to accurately determine the achievement of the required strength of concrete and linking the information about actual time lag to the model, we can simplify the process of schedule update. Moreover, we can provide reliable information that the striking can be done and when it can be done to the person in charge in an efficient way.

Further research needs to be performed in order to develop exchange templates, to verify reliability of proposed method and compare versatility of suggested approaches and evaluate most effective way of data exchange.

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