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MANAGEMENT OF STRUCTURAL INFORMATION AND CONTROLS WITH BIM

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The aim of this research is the definition of a control planning for the reinforced concrete structures in place and the organization of all this information with the aid of BIM methodology. To better illustrate the process of information flow through BIM system, structural controls and the control plan have been applied to a case study concerning a new building. The BIM model contains all the information necessary for the design, scheduling, testing, construction, operation, management and maintenance of the structural parts of the building. The use of BIM model with relevant information and control sheet has enabled us to exploit the full potential of B.I.M. during the construction phase; its main value consists in granting immediate access to as-built/as-operated building information. We created two models: the first identifies the technical elements that make up the building (LOD 100); while the second is characterized by a detailed definition (LOD 400). The frequencies systematization, organized according to the flow charts, has allowed the definition of a Gantt chart integrated with the control sheets. Controls referred to initial controls (i.e., acceptance of materials), follow-up controls and final controls. It is also possible to control and automatically update the final technical item tolerances.

Keywords: Concrete structure, Building information modeling, Quality controls.

1 INTRODUCTION

This work is an excerpt of a PhD thesis concerning the definition of a control plan for reinforced concrete structures cast in place. The procedure was systematized and finds its natural application in the BIM system. The application example that follows, tries to reallocate the operating procedures described in the previous chapters experimentally using a BIM model related to the structures of a building. The model contains all the information necessary for the design, scheduling, testing, manufacturing/construction, operation, management and maintenance of the structural parts in which only the controls-related parts have been highlighted for coherence with the dissertation.

The use of BIM has enabled us to exploit the full potential of BIM models, as its added value lies in the immediate access to as-built/as-operated building information. (Estman et al., 2011) One of the most significant problems addressed in the control sheets validation process, consisted in not being able to handle the large amount of documentation provided upon the project termination, thus losing the possibility of access to substantial data in the building management process.

According to the National Institute of Science and Technology (NIST), a typical engineer in charge of operations and maintenance spends more than 40% of the day to seek and validate the appropriate information for the project that you are dealing with. Another 15% of the day is often spent to find the information necessary to perform maintenance tasks (Gallaher *et al*., NIST 2004).

Currently, the information gathered during each phase of the building life cycle, are often lost during the transition from one phase to another. The lost information then should be at least partially "re-acquired", with an additional cost, if required. The BIM system allows players to collect and not lose the information necessary for the management and maintenance of the building, as they are placed in the project file during all phases of the building process, saving research time and cost related to the "re-acquisition" of the same. Once you have entered all the necessary information in the BIM model, it can be used by anyone for all the phases of the building process work and for operation and maintenance.

2 CASE STUDY

To better illustrate the process of information systemization through BIM system, the controls and the control plan have been applied to a case study concerning a new building (Gottfried *et al.* 2013). It is a three-floor reinforced concrete structure cast in situ, consisting of a 50 cm thickness mat foundation, a frame of beams and reinforced concrete columns braced by the staircase placed near the center, and the elevator shaft. Floors are partially made up of precast concrete predalles slabs. We created two models:

- The first model identifies the technical items the building consists of (LOD 100). The technological WBS, acts as a guide to the definition of all the parts of the work to be carried out (columns, beams, floors, etc.). Each technical item is then "informed" of all the control sheets to fill out for its proper verification during execution
- The second model has a construction purpose (LOD 400). The technical items were divided into their component processes (formwork, reinforcement and concrete). Controls are then associated to each process, control sheets will be part of the information database related to an individual BIM object.

2.1 Identification and BIM Modeling of the Technical Items and Control Plan

The preliminary modeling starts from the definition of the technical items that make up the building. The reference to UNI 8290 allows the classification related to technological units and classes of technical items. The function of each structural part is then identified: Foundation structure (foundation mat), horizontal elevation of structures (beams and slabs), elevation sloping structures (stairs), and vertical elevation structures (pillars and walls). Then we highlighted the types of technical items, their number and location in relation to their main characteristics (e.g., geometry).

The BIM model is not a three-dimensional modeling for volumes definition or structural design but a virtual model, which is used to exhaustively define a part of the building and to organize data and information in a simple and constructive manner.

Once the control plan is set according to the division for technical items, it is crucial to identify the type and location of the same.

The first model is very simple since its purpose is to attach to each technical item all the information needed for an efficient control during construction process. This level of modeling may be attached to contracts for execution to formalize the control plan, modes, timing, frequency, and the responsibility of the same. The BIM LOD 100 model, in fact, allows to exhaustively define the geometry, and consequently the acceptable tolerances for each technical item (UNI EN 13670:2010). Moreover, you can attach all the control sheets. By defining a program of controls, integrated with the work program of the yard, you can immediately plan controls in relation to the performance of the works.

In addition to the basic information regarding the size, the technical item will be supplemented by information on the requirements and characteristics of the materials, tolerances and acceptance tests, the control sheets for the control of works in progress and final inspections. Using the BIM software Autodesk Revit, this work focused on identifying, for each type of technical item, the appropriate family completed by the parameters of the information listed above.

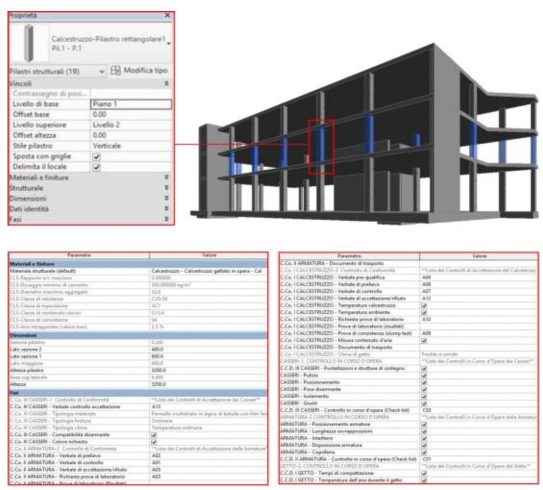


Figure 1. BIM Model (LOD 100) with control sheets.

The LOD 100 BIM model is then "informed" through the use of the shared parameters. It was decided to enter as parameters all the entries that deal and examine in-depth the quality control during construction of the technical item studied (pillar). Five categories of definitions were identified and grouped:

1) Requirements and properties of materials

2) Dimensional tolerances

3) Control of acceptance

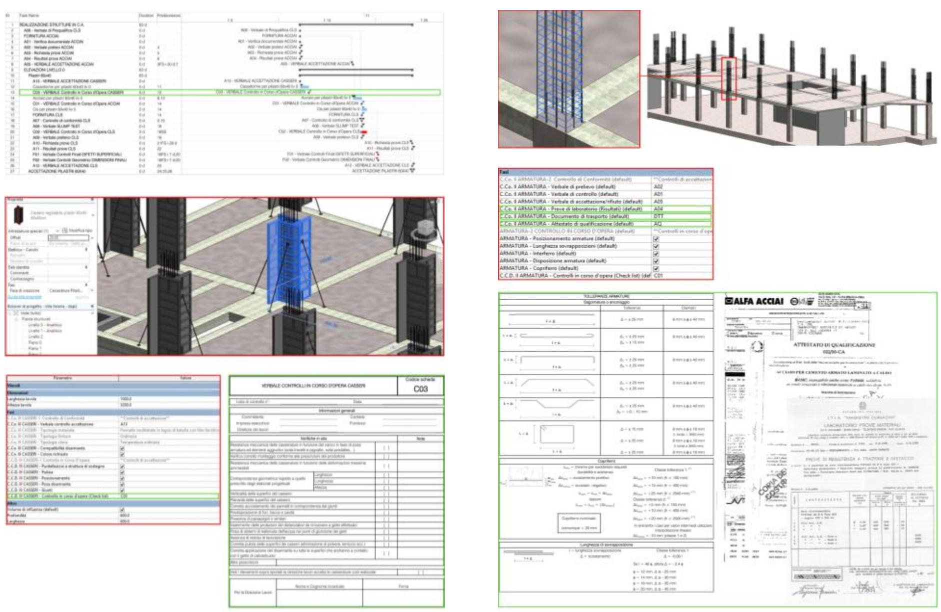
4) Inspections during construction
5) Final checks

These information categories include entries that specify the type of information required. Entries can be filled with: values to be written inside the box; check reminder (to check or not, if performed); attached checklist forms to be filled externally to Revit, which are part of it as technical item information.

The definition of all this information allows a better definition of the project as well as a better prediction of the progress of the work construction phase. Below, you can see the "Properties" dialog box for the pillar item analyzed with all the technical specifications and parameter values and/or the attached forms.

2.2 Control Planning and Scheduling

The frequencies systematization has allowed the definition of a Gantt chart integrated with the control sheets. The controls were included as milestones (better benchmarks), with the exception of the controls during the work on concrete that have been incorporated into a single report, but with references to different times as inspections refer to all phases and therefore have a length equal to the processing duration. In the Gantt chart they were marked in red to indicate that they are controls and not activities.



(a) (b)

Figure 2. BIM Model with formworks follow-up control (a) and steel follow-up control (b).

Before the supply of concrete, the prequalification of the production center is required. Following the steel supply, you can start the checking and acceptance process, consisting of documentary verification, sampling from the report of the steel bars based on the project manager’s request for an official laboratory test. Only after the laboratory results are received, you can accept the delivery. In the Gantt chart 30 days are allowed, because this is the maximum time limit that defines the rules for acceptance of steel supplies. Thus, the maximum times for acceptance of the material prior to its use are allowed.

Simultaneously with the steel supply steel, it is possible to have formworks on-site supply. In relation to the type and quality of the desired and prescribed casting, formworks must be accepted before being used. Only then they can be installed and you can check them during the construction of the formwork. In this manner, joints are checked along with the laying of panels, the release agents, etc. At the end of the reinforcement laying, the control during construction of the reinforcement is scheduled.

Finally, the diameters of the bars installed, the distance between the plates, the concrete cover, the overlaps, etc., are checked. The supply of concrete allows you to start the acceptance tests of the same and then do initial inspections aimed at compliance, the workability test and the sampling. Controls during the construction phase include checking procedures both for casting modalities and their seasoning: for this reason they do not have zero duration but last all the time required for the concrete casting. Following the removal of the formworks, you can perform the final check. Final acceptance of the technical item, however, can be done only upon the request for concrete testing to an official laboratory and upon check of the results by issuing the concrete acceptance report.

2.3 Tolerances Control

The construction tolerances are the maximum and minimum acceptance values of a technical item installation (Taylor 2006). Tolerances regarding pillars are summarized in:

- Tolerance distance between adjacent elements: the element defined in relation to the distances from the pillar to adjacent elements. As you can see from the figure included in the program, it has been defined through the use of two auxiliary parameters, called Distance y and Distance x, which define exactly the distances of the cardinal pillar analyzed from adjacent elements.
- Tolerance by positioning a vertical axis: defined by the interfloor heights.
- Cross-section orthogonality tolerance: defined by the size of the section.
- Cross-section obliquity tolerance: defined by the size of the Pillar's section.
- Curvature tolerance: defined by the interfloor distance between two decks.

All these parameters have been defined by formulas indicating the limit values and compare them to the actual values of the model items. Further, this discussion was also integrated with a parameter included in a table summarizing the case studies of dimensional tolerances for separators and pillars according to the UNI-EN 13670:2010.

However, the resulting values are related to the tolerances and, as such, are to be considered as absolute values that may allow deviations calculated in both directions.

The excerpt below displays the screenshot showing the model and the properties associated with the item technical drawing.

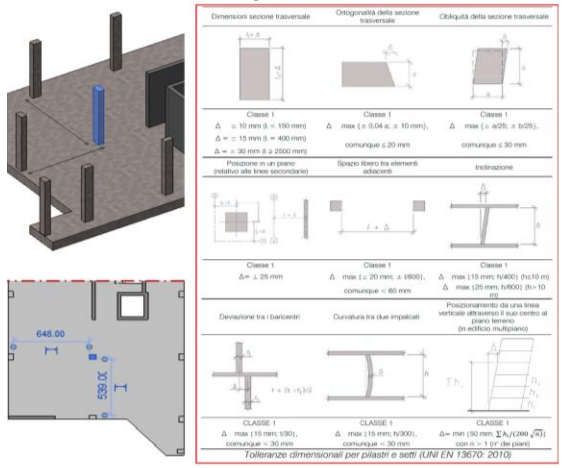


Figure 3. BIM Model with tolerances control.

3 CONCLUSIONS

The control sheets processed, constitute the optimal basis for a quality control plan and, in particular, for a control plan aimed at the execution of civil works in reinforced concrete cast in place. The method used allows formalize controls by including procedures and control sheets in the specifications. It also allows to define and explain the requirements and specifications with which to inform the structural design. This process increases the expected quality of the implementation phase, enabling us to thoroughly check each building step and identify in a timely manner, any possible process non-compliance. The procedure and controls defined are integrated into BIM system as well. It is possible to associate each technical item with regulatory requirements and specifications to be used in the design phase and the subsequent control modes to be implemented during the execution. By doing so, the computerized controls both during construction phase and information transfer for the next testing and management phase are ensured.

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