The optimization of the number of reinforcing bars in the slabs in grasshopper and integration with TEKLA and LIRA-SAPR

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Abstract. The article reveals the interoperability of several software products. The concept of interoperability of software products is supported by OpenBIM standards, providing a project with a reliable platform and open source code for integrating BIM models with other environments. It is possible to exchange data between software systems, not only through the IFC format, in the article we will consider other means of information exchange. An algorithm is formed that optimizes the number of the number of reinforcing bars in the slabs. The optimization is possible due to the interaction of different software systems through plugins.

Key words: BIM, OpenBIM, TEKLA structures, LIRA-SAPR, Rhinoceros, Grasshopper, Script, Finite Element Method.

1 Introduction
The aim of the study is an analysis of the integration of different software products for required compatibility with the work data for building information modeling. The firm has the necessary set of software products and a BIM-standard for import and export of physical model, analysis model, 3D-model, meshed model and finite element method between different software products that support the OpenBIM concept.

The main objectives of the study:
1) the analysis of interoperability of software products and the development of an algorithm for optimizing the number of reinforcing bars in the slabs in the case of building information modeling;
2) the optimize the number of reinforcing bars in the slabs on the base of building information modelling for the firm of construction industry.

1.1 Literature review
BIM is the creation of an information model of a building, the representation of the capital construction object and each of its elements through the totality of parameters, characteristics and properties assigned to it [1].

The assignment of characteristics and properties can be implemented in various software systems developed on the basis of building information modeling [2]. An open information system in architecture, engineering, construction and operation (AECO) in the life cycle is implemented by the OpenBIM approach. The team work of specialists is carried out in various software products on an open specification data format: Industry Foundation Classes (IFC) [3].

However, the main problem of firms in AECO is that not all data of model can be transferred through the IFC format. At the time there are platforms thanks to which it is possible to create a
parametrical model and transfer the data to other software products without losing the collected required data.

OpenBIM standards and the IFC format are urged by the need for a common exchange between discipline's models and the effective information management. One of the main obstacles to the implementation of BIM for ensuring effective cooperation and communication in investment project is the diversity and heterogeneity of the output information [4].

Implementing a universal platform for referencing processes and an information throughout the life of an asset can potentially destroy issues related to software incompatibilities. As an attempt to solve this problem, the buildingSMART alliance developed an OpenBIM approach based on open standards and formats [5].

The BuildingSMART main focus is on data and technology, to a lesser extent on people and processes. The OpenBIM concept initiated a collaborative approach among a wide range of disciplines where different users can use specialized software and store a variety of data in a unified model.

The result of this efforts was to create a common platform for exchanging information in a common language, which allows participating in the project regardless of the software used [6, 7].

The IFC is the main provider of a model data developed by BuildingSMART, a data format with an open specification that is not controlled by any company or group of companies [8, 9, 10, 11].

The IFC is used as a format for the BIM building information model and is now supported by many software developers supporting the IFC import / export function. The IFC is an extensible object-oriented data model, divided into basic entities and sub-entities. This format classifies and gives structure to the data that makes it easy to retrieve various sets of information.

The consistency of the data in the format is aimed at eliminating the need to enter the same information several times, thereby minimizing errors and allowing the project team to focus on the compatibility of their work processes.

The OpenBIM approach can serve as a means to achieve a free choice of software, where companies and users can choose the software that is most convenient for them to use the required tools and most effectively show their capabilities in design [12, 13].

The different needs of the professionals involved in the project throughout the life cycle, several types of geometry, properties and relationships are needed. IFC preserves data structures inherited from its own format - geometry, logical relationships and attributes of three-dimensional elements.

However, in order to adapt to all types of geometry and properties [14, 15, 16], the IFC format is redundant. Consequently, coordination and communication data collection is becoming increasingly complex, despite the compatibility of the formats.

As a result, high complexity leads to lower usage among professionals, where a limited understanding of import and export leads to translation errors and hinders compatibility [17, 18, 19, 20, 21]. In response to this IFC redundancy, many studies have proposed various logic checks to ensure open information compatibility and data consistency to minimize data loss during transmission through IFC [22, 23].

2 Materials and methods

The finite element method (FEM) is a numerical technique used to perform finite element analysis of any given physical phenomenon. The calculation by the FEM of the load on 2 types of reinforcement, longitudinal and transverse in slabs is made in LIRA-SAPR.

Then, data in Excel format is exported from LIRA-SAPR, in this file, after calculation by the FEM, slab elements are exported, and the loads on the reinforcement in the elements are recorded (table 1). Several tables are also exported. In another table, the coordinates of each point of the element are painted by elements. Thanks to access to these files, it is possible to re-arrange the elements in the coordinates and perform the required calculations on the loads in the reinforcement and assign them to each element.

LIRA-SAPR supports the OpenBIM interoperability concept and interacts well with the TEKLA Structures program. In the company where the task was solved, the LIRA-SAPR calculation program
was purchased, even before the task was set, therefore, all calculations were performed in this program and other calculation programs were not considered.

Table 1. The elements table with assigned reinforcement loads.

| Elements | Reinforcement | Reinforcement | Reinforcement | Reinforcement |
|----------|---------------|---------------|---------------|---------------|
| 261447   | 0.06          | 1.23          | 0.06          | 0.35          |
| 261447   | 0.06          | 1.23          | 0.06          | 0.35          |
| 261448   | 0.06          | 0.69          | 0.06          | 0.06          |
| 261448   | 0.06          | 0.69          | 0.06          | 0.06          |
| 261449   | 0.06          | 1.2           | 0.06          | 0.8           |
| 261449   | 0.06          | 1.2           | 0.06          | 0.8           |
| 261450   | 0.06          | 0.06          | 0.06          | 0.06          |
| 261450   | 0.06          | 0.06          | 0.06          | 0.06          |
| 261451   | 0.06          | 1.23          | 0.06          | 0.57          |
| 261451   | 0.06          | 1.23          | 0.06          | 0.57          |
| 261452   | 0.06          | 0.06          | 0.06          | 0.06          |
| 261452   | 0.06          | 0.06          | 0.06          | 0.06          |
| 261453   | 0.06          | 1.21          | 0.06          | 0.35          |
| 261453   | 0.06          | 1.21          | 0.06          | 0.35          |

Source: Authors Model from LIRA-SAPR software.

3 Results
According to the OpenBIM concept, a bunch of three software was produced: Rhinoceros with the Grasshopper plugin, LIRA-SAPR and TEKLA Structures.

The primary task was to transfer data from LIRA-SAPR software to make calculations and subsequently transfer it to TEKLA Structures. In the Rhinoceros software package in the Grasshopper plugin, an algorithm has been developed that performs calculations based on the received data from LIRA-SAPR, after which a new model is built according to the calculations and the data is transferred to TEKLA Structures.

The algorithm depicting the reconstruction of the geometry and the required calculations according to the data from the tables from LIRA-SAPR is shown (figure 1).

Figure 1. Script in Grasshopper, optimizes the amount of reinforcement.
Source: authors model based on in-depth expert interviews from Grasshopper software.
As a first step, the table is integrated into Grasshopper, as a next step we developed our own node in the information system, written in the C# programming language, it removes duplicates and other data that do not correspond to the required parameters for geometry reproduction.

Subsequently, a group of standard nodes in Grasshopper reconstructs the geometry and assigns reinforcement load values to each element. The next step is to optimize the number of reinforcements.

According to the data from LIRA-SAPR, there is an overspending on the number of reinforcements, it is possible to reduce the quantity, at the moment the choice is made by a specialist on site.

The algorithm developed at Grasshopper automatically optimizes the amount of reinforcement. In places where the load on the elements varies within the required values, it is necessary to leave one type of reinforcement, in elements where a jump occurs outside with the nearest elements, a different type of reinforcement is set, also if the section is homogeneous, but the length of one reinforcement exceeds the limit value, a new reinforcement is created. A mathematical model that optimizes the amount of reinforcement was described by its own node, written in a C# programming language. Two lists are shown in (figure 2).

![Figure 2](image)

**Figure 2.** Load lists for each valve.
Source: Authors Model from Grasshopper software.

On the left is the original list, on the right is an optimized list. According to the specified criteria, some values were averaged and it turned out from 25 different values of 5 groups with the same values. Based on these data, 5 types of reinforcing bars will be required in this section, which will also bear the load in the slab. Next, new values are overwritten for each element. A check for deviations before sending (figure 3).
Figure 3. Load graphs with percentage error of the optimizing algorithm.
Source: Authors Model from Grasshoppper software.

On figure 3 is a visualization of the load on the reinforcement in the slab. The lower red polygons are a slab divided into many elements, created after calculating the loads in LIRA-SAPR: the yellow line is the section of the slab reinforcement, the white graph is the initial loads, the black is the optimized loads. On the right, numerical data is the percentage of the errors between the original and optimized graphs. An error within 5 percent is considered permissible. The graph shows that the error is less than 1 percent.

The next step after verification is the transfer of the geometry with the assigned data to TEKLA Structures. Grasshopper and TEKLA Structures have a middleware plugin that makes it possible to transfer data.

4 Discussions
This development corresponds to the OpenBIM concept in which various software systems interact, performing more effectively their part of the overall system.
Currently, only load data is transferred to Tekla Structures from Grasshopper without building a solid model. The algorithm is under active development to build a solid-state model of slabs and reinforcement in Grasshopper, for transferring a full-fledged model with load properties to TEKLA Structures with its native components.

5 Conclusions
The main objectives of the study were solved:
1. An algorithm has been implemented to optimize the number of reinforcements bars in the slabs and regulations have been developed for importing and exporting from software products Grasshopper, TEKLA Structures, LIRA-SAPR. As a result the number of reinforcing of bars was reduced by 35 percent.
2. A check of the mathematical model was made on an applied example, that optimizes the amount of reinforcement described by its own node, which shows that the error is less than 1 percent.

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