

Review of open source software for modelling and analysis of structures

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Abstract. The open-source software attracts the engineering society with the accessibility, the chasing of processes, the flexibility and the possibility of making changes to the interface or in the program code processes. This paper presents the results of a comparative review of several groups of open-source software (OSS) for modelling and analysis of constructions. The advantages and challenges of working with OSS in comparison to the use of widespread products with commercial licenses are analyzed. Software products of two categories are considered: (a) geometrically /graphically modelling/ drawing of the structures - 2D, 3D CAD; (b) calculation and analysis of building structures under different load conditions and geometry including geotechnical problems. The software products selected for the purpose of the report are compared based on the performance of a simple engineering task from practice. The sufficiency of the results, the options for presenting the data and other additional characteristics of the products are commented.

1. Introduction

Despite the vast publications, related to BIM modeling in the field of structural engineering and architecture Free/Libre Open Source Software (FOSS), still represents an unexplored territory, which interests the engineering society. To investigate the potential inherent in software for the main structural engineering essential parts – modeling, analyses, and geotechnical problems, *imprimis* we have to describe the benefits in the OSS [1].

The OSS movement was pushed by the Symbolic's (AI LAB) resolution to use non-free timesharing systems instead of ITS and IMB's policy changes in 80's, which contains closing the software architecture thought object-code only (OCO) [2,3]. The customers weren't allowed to use the source code of programs, because of the restrictions, therefore they were not able to control or govern the program result. These drastic changes in distributing software empowered the IT community to developed free/open software. The well-known results of FOSS movement are GNU Emacs free/libre text editor, developed by Richard Stallman, and GNU Operational System (OS). Stallman started GNU (GNU Not Unix) project, which objectives exemplify the idea of "copyleft" – the method for redistributing and modifying free software [4]. Late Stallman founded Free Software Foundation (FSF), a nonprofit organization, which published one of the most popular free license General Public License GPL, the legalization of copyleft, and documentations for redistribution, modifying and developing free software, but without adding additional cost or restrictions for the users. [5]



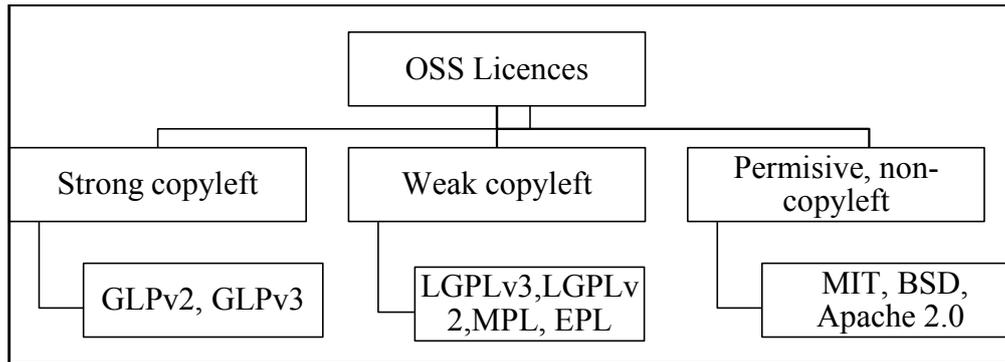


Figure 1. The OSS Licenses types, approved by OSI

FSF disseminated the substantial for the OSS movement the strong copyleft GPLv2, GPLv3 licenses, which been approved by Open Source Initiative (OSI) [5]. They are applicable for widespread open-source software and ensure the user's freedom, but coerces the customers to releases the final product of modified source code, under the same license type as the original software, also including the availability of source code. Lesser General Public License (LGPL), considered to be a weak copyleft license like Mozilla Public License (MPL), Eclipse Public License (EPL), permit distribution of application under the proprietary license agreement, in fulfilling certain requirements. The weak copyleft licenses necessitate the distribution of the binary code with corresponding copyleft-covered sections of source code. The permissive non-copyleft licenses Berkeley Software Distribution (BSD), Apache license, MIT License, approved by OSI, permit using the source code and redistribute it under the proprietary license.

The preference of the OSS application is not only under reliability, a result of accessibility to source code, but the addition of contribution of customers to the final product and maintenance of the source code in internet OS libraries or software development platforms. [6]

2. Geometrically and graphically modelling of structures

Computer-Aided Design (CAD) is prevalent in the field of structural engineering and architecture in the last few decades. The CAD software applications, part of OSS movement, for the purpose of the report, will be considered as 2D CAD and 3D CAD.

The AEC /Architecture, Engineering and Construction/ companies are providing CAD performance of their project, consequently, they have to consent with licensing policies of the closed software distributors, which dominates the market [7]. The usage of CAD software is also included in engineering education in AEC universities with student's versions, limited in provided functions and/or period of usage, commonly year or all-time of education. This established financial issues of graduated students and small AEC firms in the field with the acquiring CAD software. The OSS alternatives of CAD proprietary software provide to the customers equal functionalities without restrictions and additional costs.

2.1. 2D modelling

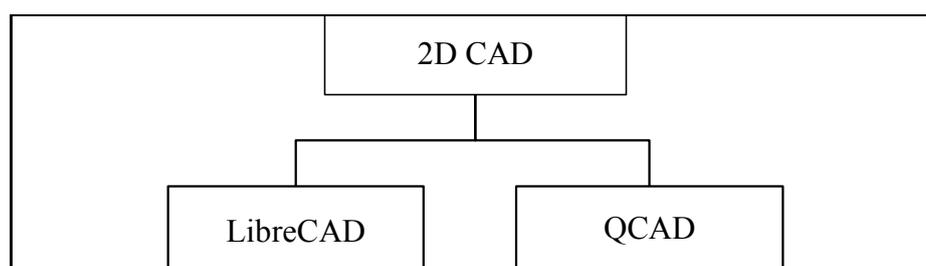


Figure 2. 2D CAD softwares, considered for the purposes to the report

The selection of relevant criteria for evaluation of 2D OSS from a scientific perspective is of particular importance. As consequence, the criteria are summarized in two different sections – “documentations” and “functions” in the evaluation list, in which the assessment is shown by a range (1) for poor to (5) for fulfilled. The section “documentation” includes the valuation of intelligibility of existing manuals and tutorials and the customers’ support in forums, and also readily available GUI of the software. A variety of accessible geometric features, annotations and generated libraries are included like objectives in “functions” criteria. The researched date established more CAD software closed or limited, nevertheless the report considered to represent only OSS software and evaluated it. [8, 9]

2.1.1. LibreCAD

LibreCAD is an open-source 2D CAD application, released under GPLv2 for Windows, Linux, macOS and Unix operating systems. The latest version of the product LibreCad 2.2.0 series is based on Qt5 libraries. The native file format of the application is dxf, furthermore, LibreCAD supports pdf and image formats. The inability to export to dwg file format is one of the major limitations of LibreCAD, nevertheless, it supports partially dwg for import.

The LibreCAD 2.2.0 series are available in desktop and portable version, which doesn’t need installation. The application is suitable for 2D representation of the project, as a result of a wide range of geometric features, annotation’s tool and print options. Different libraries and blocks are generated in LibreCAD, which considerably simplifies the operating with complex projects. Online training, manuals and forums are available on LibreCAD website.

2.1.2. QCAD

QCAD is 2D CAD open-source application for Windows, macOS and Linus operation systems, developed by Ribbonsoft and released under the General Public Licence version 3 (GPLv3) license. The OSS, called QCAD Community edition provides a wide range of geometric features, which, however, are severely limited in comparison with QCAD Professional, commercial proprietary software, also developed and distributed by Ribbonsoft.

QCAD’s native file format is dxf, but likewise LibreCAD, the program supports pdf and image file formats for import and export. QCAD Professional and QCAD/CAM, at the same time, can export and import in dwg file format. The application provides the indispensable features for 2D representations of projects.

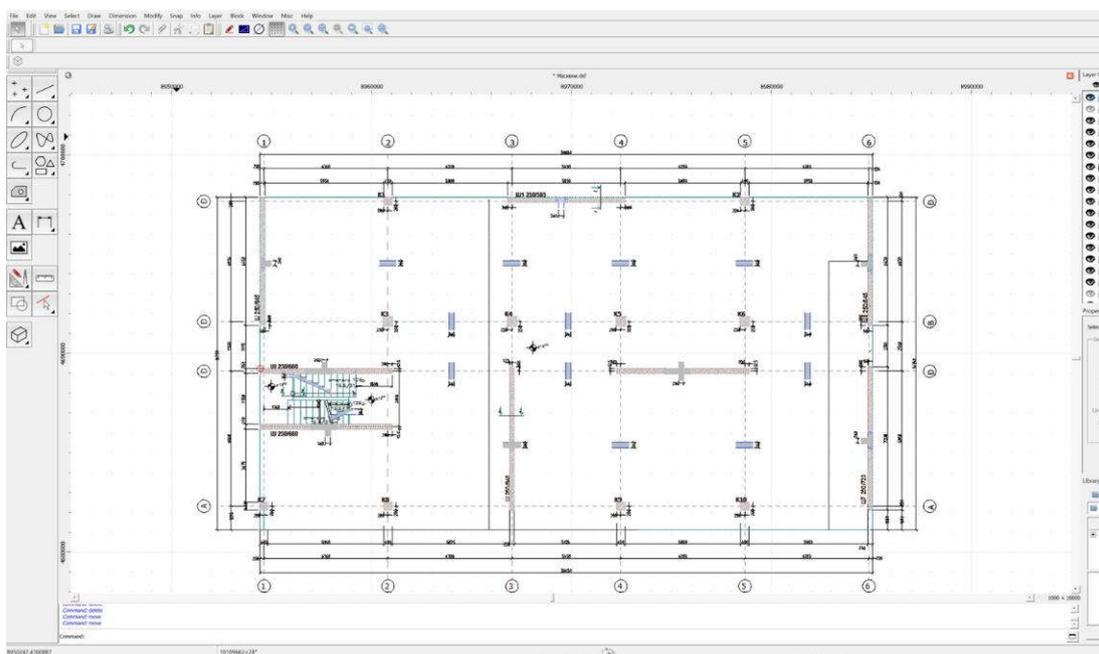


Figure 3. 2D CAD representation of the concrete building in GUI of QCAD

Table 1. Comparing 2D CAD open-source programs LibreCAD and QCAD

	LibreCAD	QCAD
Documentations	3	4
Functions	4	5
Languages	4.	3
Supported units	5	5
Export/Import file format	3 /BMP, JPEG, TIFF, ICO, PPM, XBM, XPM, SGV, PDF, DXF, CXF, and DWG	2 /BMP, JPEG, TIFF, ICO, PPM, XBM, XPM, SGV, PDF, DXF, CXF/
Print options	3	3
Drawing tools	3	3
Text settings	4	4
Snap options	4	3
Block tools	2	2
Libraries browser	4	3
Dimensions	4	4

The result of the comparison of the LibreCAD, QCAD and the commercial software, widespread in the field of AEC industry has revealed strengths and some critical aspects. One of the major limitations of OSS is the inability to support dwg file format, nevertheless, they have open-source code, which allows the community to contribute to the software. The comparison of the LibreCAD and QCAD also revealed some limitations in both of the applications. In our opinion, the graphical user interface of QCAD is more user-friendly and the geometric features provided more options for the representation of the project. The commercial version of the product, on the other hand, raises an issue for the subsequent development of the application.

2.2. 3D modelling

Building Information Modelling (BIM), a rich, manifold and widespread field of research, remains unexplored territory in experience with OSS. First OSS tools for the implementation of BIM projects, are developed, in an exclusive form, by big IT companies. Nowadays IfcOpenShell, open-source software libraries, and Open Cascade Technology (OCCT), a platform for 3D, CAM software development, represents an irreplaceable basis for both OSS and proprietary 3D software. [10,12,14]

2.2.1. FreeCAD

FreeCAD, 3D CAD/ CAE parametric modelling application, is free alternatives to proprietary BIM software, developed in 2001 by Jurgen Riegel. The FreeCAD Project was called Graphical Object modeler (GOM), which impalement Open CASCADE, Phyton and Qt multi-platform languages. First inspired by Catia V5, well-known proprietary design software, nowadays FreeCAD is a multidisciplinary software application, due to long term active collaboration of developers and users. Arch, Draft, FEM, Image, Inspection, Mesh, OpenSCAD, Part, Path, Plot Points, Raytracing, Reverse, Robot, Ship, Sketcher, Spreadsheets, Surface, TechDraw are some of the active workbenches, part of

the application. FreeCAD is released under LGPLv2+ license, which is considered to be a weak copyleft license.

The application allows customers to use Graphic User Interface (GUI), Python scripts in Python console and Macros for modelling the building, structure or detail.

Its native file format is FreeCAD Standard file format (FCStd.), nevertheless, it supports dxf, dwg, svg, stl, SCAD, IFC and other file formats. The Arch and BIM Workbenches provide features to create 3D model of building or structure, but on the other hand, FEM Workbench submits complex finite element analysis, which presents the FreeCAD like OSS also for calculation and analysis. [13]

The concrete building was designed in both FreeCAD, open-source software, and Revit, well-known proprietary software, for the ability to consider all the problems, related to the phase of modelling and representing, and proper evaluation.



Figure 4. Model of the concrete building for evaluation

The comparison, during modeling of construction, revealed some critical aspects in FreeCAD, focused on representing AEC objects, but on the other hand, the application provides opportunities to calculate and design complex geometry by using scripts or macros. [9] Libraries, online training, manuals and forums allow the customers to use all features of this multidisciplinary software.

3. Calculation and analysis of building structures and geotechnical problems with complex geometry

The development of more powerful hardware in the last few decades has led to the rapid expansion of software solutions in all engineering areas. The software application allows engineers to design complex structures efficiently and decreases the number of mistakes and errors.

Code Aster is one of the most famous OSS FEM codes for calculating almost every engineering task. Many other also commercial types of software are using the code only as a solver. Calculating the cantilever beam is considered to be designed in Code Aster for the purposes of the report. Modeling and calculating the beam is the fundamental prerequisite for the evaluation. The results are comparable with the results of STAAD Pro for the same section and load, but the design is much more complex and requires knowledge in programming in Python. Nevertheless, Code Aster is one of the widespread OSS for the calculation of complex structures.

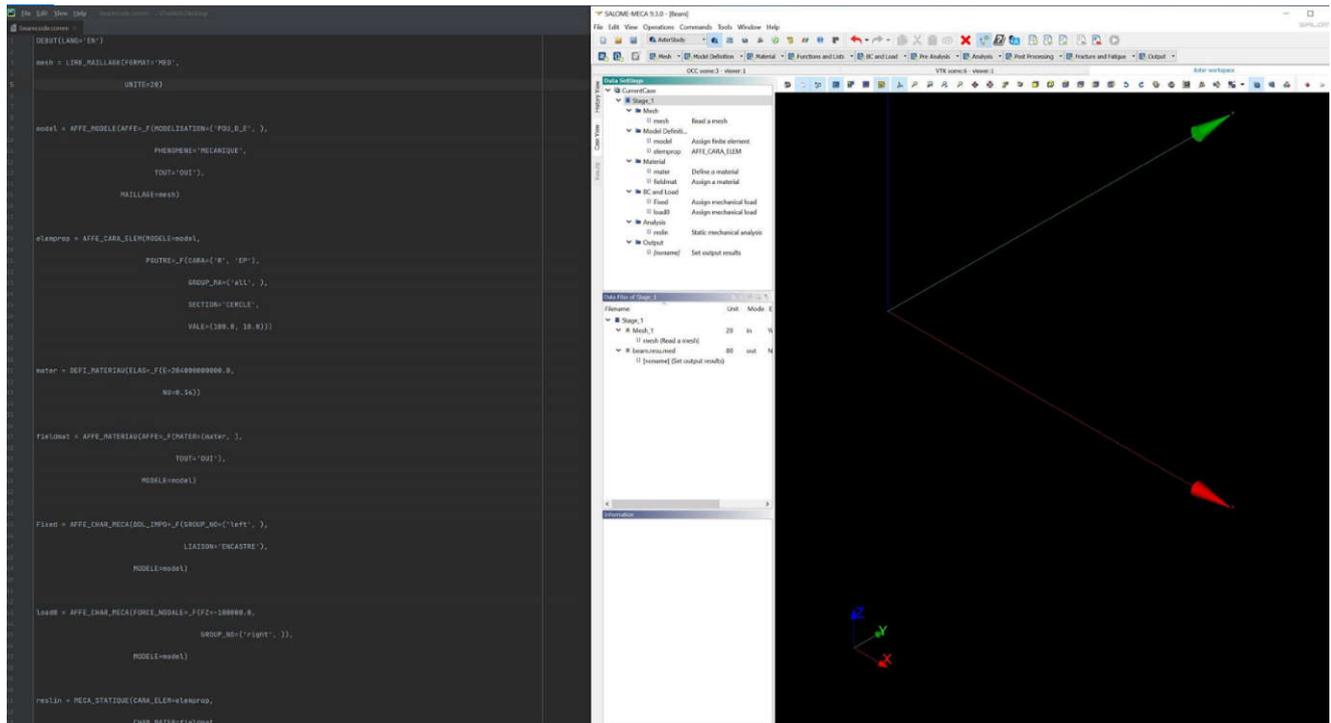


Figure 5. Python code for calculation of cantilever beam in Code Aster

Code-Aster, build in Fortran programming language, is released under the LGPL license. Code-aster combined with the GUI and the powerful pre- and post-processor Salome is released as Salome-Meca. The biggest issue with Code Aster and Salome-Meca was the documentation in French, but lately, there is full English support. Since version 17 Salome-Meca is also available for Windows. Version 19 of the software supports CAD-like Model construction and it is already the most powerful OSS software for FEM Analyses including some aspects in Geotechnics.

There is a vast majority of OSS software for Geotechnics, but almost none of them is general-purpose geotechnical software (solve only one task). Based on the difficulty of the geotechnical field, most of them are either task-oriented or sophisticated code-oriented executable that doesn't support GUI. Barkley University OSS geotechnical software is an example of the last one.

One remarkable OSS, software for Geotechnics is the early developed software with the name ADONIS. The author knows well the already described problem with the geotechnical OSS and tries to implement code, GUI and sophisticated material models in one application.

ADONIS is 2D Finite Element Software for Geo-Engineers. It supports different element types that represent soil body, retaining walls, anchors, geogrids etc. in the model. It supports also geotechnical calculation types as settlement, excavation (also of tunnels), slope stability etc. The software is still in development under LGPLv3. Further would be a dynamic simulation, so the contribution to such type of software is always a good idea.

4. Conclusion

Software, considered for the purposes of the report, has advantages and some critical aspects compared to proprietary software in main structural engineering essential parts – modeling, analyses and geotechnical problems. The choice of the right software is determined by the needs of the customer – 2D CAD, 3D CAD or software for calculations and analysis, nevertheless the license's cost and agreements are a substantial part of the decision. OSS provides the comparable functionalities to proprietary software without restrictions and additional costs.

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