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SECTION DE GÉNIE CIVIL

Development of a Python-Based Simulation Tools Library for Composite Steel Concrete Structures

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1. Introduction

The software tools for developing nonlinear models require a vast knowledge on nonlinear analysis, for steel, reinforced concrete and, especially, composite structures. Thus, the necessity for a library that can support the user. On the other hand, the reinforced concrete and steel frames (or RCS frames) are interesting alternative over the traditional RC or steel frames because they offer several advantages over the traditional structure. In different studies, the applicability for mid to high seismic regions is shown. Nonetheless, the nonlinear model of RCS frames is currently under research. The scope of Thesis are to develop a python-based library with simulation tools to help the user to model steel, reinforced concrete and composite structures and to propose a reinforced concrete and steel (RCS) subassembly model that effectively predicts the real behaviour with a nonlinear frame analysis program.

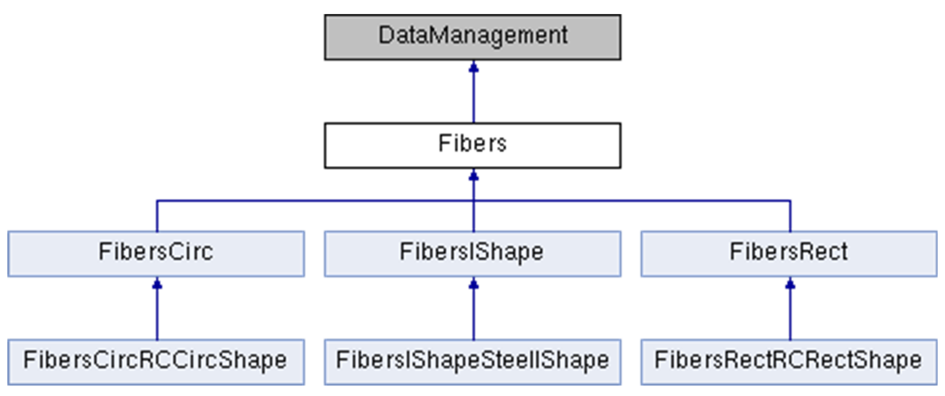
2. Advantages of the Library

The library OpenSeesPyAssistant computes automatically the required parameters; by simplifying the modeling of a structure, it makes nonlinear modeling more accessible; it is designed for flexible, readable, systematic, structured and reliable coding; it simplifies the migration of data for the post-processing; the installation is quick and easy, with just one prompt; the user can navigate in the online documentation; there is the public GitHub of the project with examples, explanations, source code.

OpenSeesPyAssistant logo

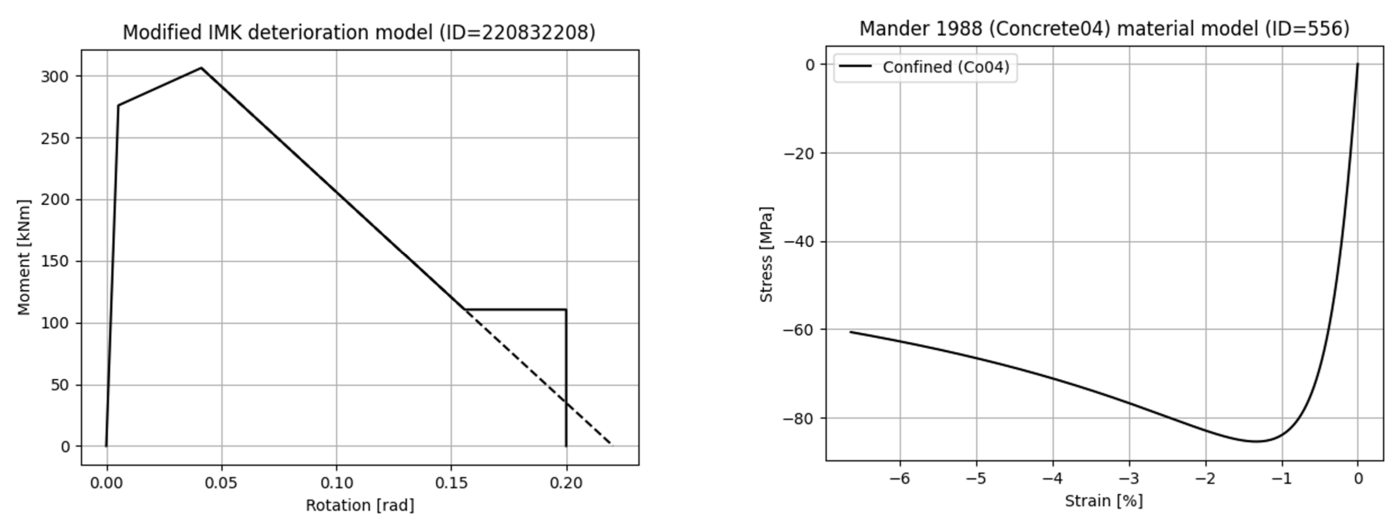
3. Structure of the Library

The main structure of the library is the exploitation of the hierarchy class feature to avoid repetition of methods that are in common, to create an imposed number of requirement to define a new class and to allow the user to switch easily between classes with the same parent class.



Example of the class diagram for the Fibers module

In addition, by using classes to implement each part of the library, two more advantages can be observed: the quick and reliable management of groups of stored information by passing just one argument, namely one object and the customization of functions with the same name that applies differently according to the situation (for example the method "ShowInfo" applied on two different objects; it can be depicted in the figures below).



Examples of the automatically generated plot from the method "ShowInfo" called from the class "ModifiedIMK" (left) and "Mander1988" (right) or child classes of the OSPA package

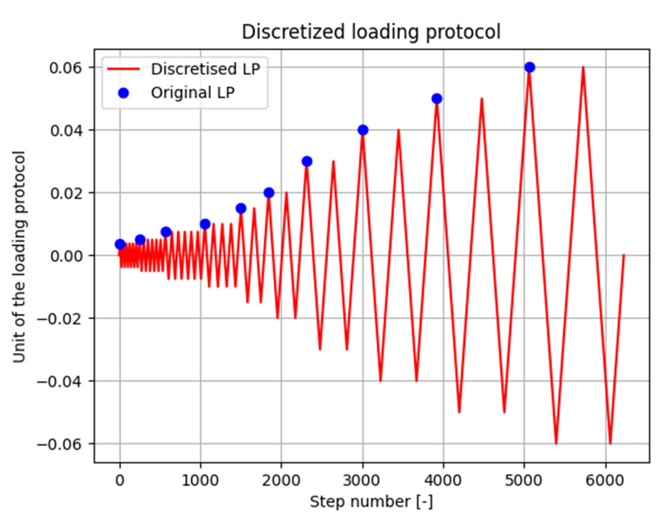
4. Features Implemented in the Library

A module manages the units, which is crucial for consistent coding of nonlinear models. Coupled with it, there is a module that stores a collection of constants, which are coherent with the units used.

The library has implemented an error handling system with the exceptions acknowledged by the author.

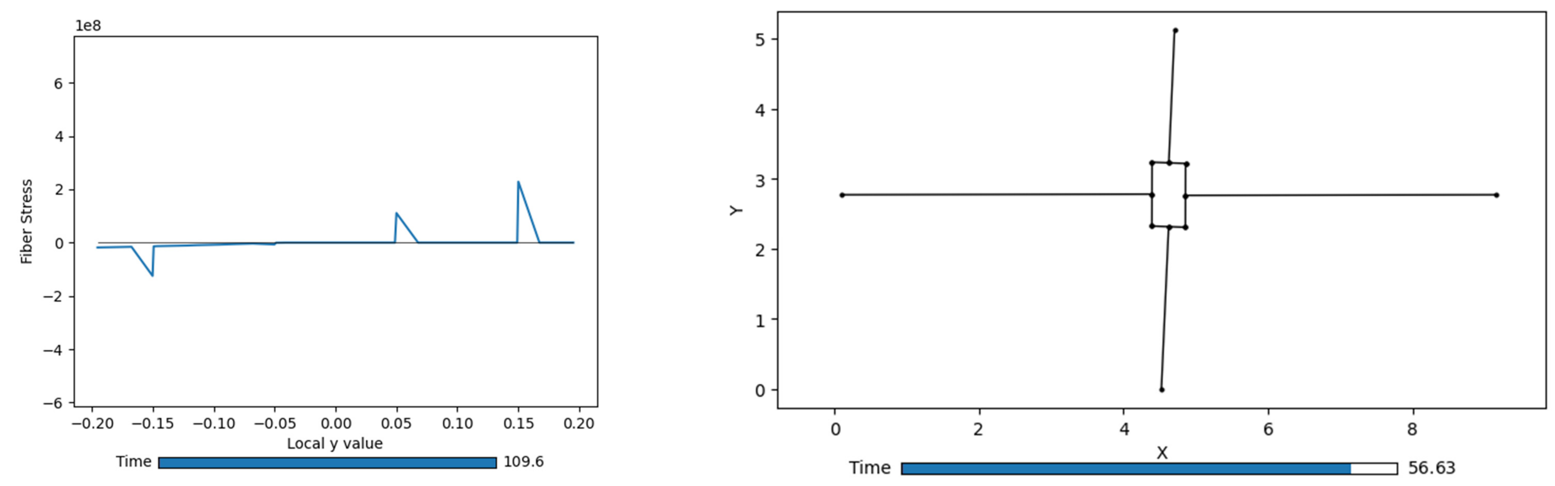
An entire module groups together different functions that are useful during the nonlinear modeling; two examples are the ID convention management and the discretization of a curve (see figure to the right).

Different analysis are already integrated in the package: gravity, lateral force, pushover and loading protocol.



Example of the loading protocol generated with just the peaks (automatically generated by OSPA)

Each analysis performs a convergence analysis if there are convergence issues and after the completion of the analysis, the animation of the deformed shape and the fiber section response can be plotted. Two frames of the animation automatically generated by the library are exposed below.



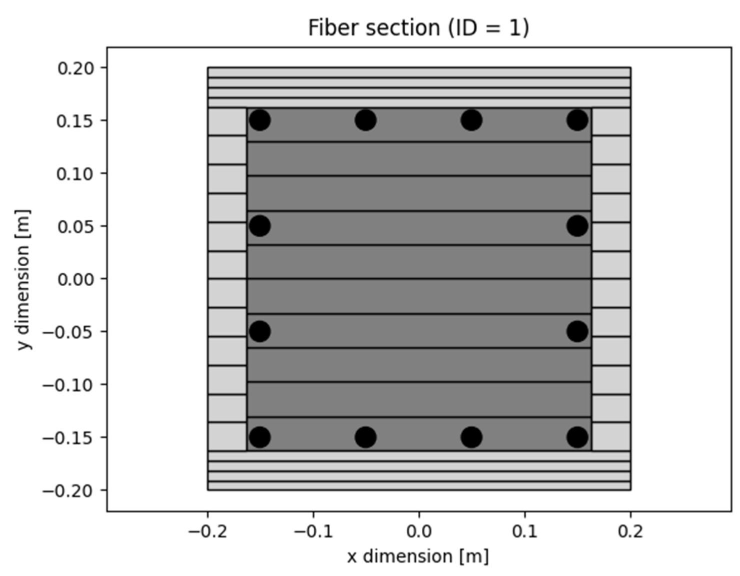
One frame from the automatic animation of the stress in the fiber section (top) and the deformed shape (bottom) generated by OSPA

Different sections are implemented using classes meant to store, manage and compute geometrical and mechanical parameters of a defined section. These sections are steel I shape, reinforced concrete rectangular, reinforced concrete square and reinforced concrete circular sections.

The material models implemented are Modified Ibarra-Medina Krawinkler, Updated Voce-Chaboche, Voce-Chaboche, Giuffré-Menegotto Pinto 1970, Skiadopoulos at al. 2021, Gupta et al. 1999, Mander et al. 1988 and simple uniaxial bilinear. The classes that defines them can automatically compute the parameters required.

The management of the geometry, parameters and definition of the fiber sections is integrated (see figure to the right for and example).

The shapes currently available are I shape, rectangular and circular..



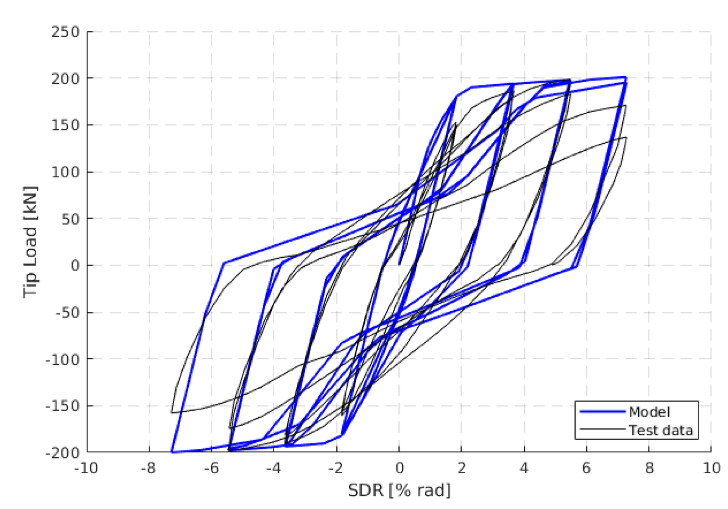
Fiber section with discretization and different color for each material model (automatically generated by OSPA)

The last module is one of the most complex because it hanldles the decalration of additional nodes, zero length element, line elements, fiber sections and material models. As the name said, it manages the member models (see Fig).

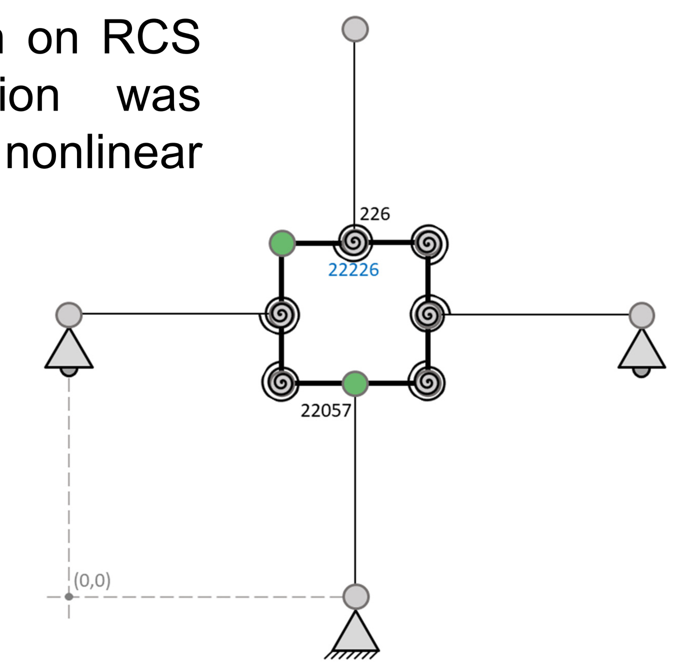
Finally, the following member models are implemented: elastic element, force-based element, gradient-inelastic flexibility-based element, spring-based member and panel zone member.

5. RCS Proposed Model

In addition to the library, a thorough research on RCS (reinforced concrete and steel) connection was performed, leading to the proposition of a nonlinear model schematized in the right figure.



Results of the application of the proposed model



Proposed RCS model (green for pinned connection, thick line for rigid elements, springs for zero-length elements)

In the figure above, the application of the proposed model is presented, showing promising results. The OSPA library was exploited to model the specimen tested.

6. Conclusion

The developed library presents different advantages that can be exploited by the users and that allow more accessibility on nonlinear modeling. This is an essential point because the nonlinear analysis of structures is becoming crucial for the design and assessment of structures, thus being able to introduce this practice to a wider range of engineers, by simplifying the coding and by lowering the entry point based on the modeling knowledge of the user, can have beneficial effects on spreading the use of nonlinear modeling. In addition, it can be used in the research field by researchers that are experts in the modeling practice and would like an alternative way to code faster and easier.