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To cite this article: Mariana Zimbru and Roberto Tartaglia 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **473** 012038

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Preliminary Finite Element Analyses on the Experimental Mock-Up Frames of FREEDAM Research Project

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Abstract. Recent research ventures focus on structural systems characterized either by low-damage or easily repairable solutions. In this context, moment resisting frames (MRFs) equipped with friction joints represent a viable option. Among the different types of friction beam-to-column connections, the arrangement with symmetric friction devices are very effective to provide stable and ductile friction hysteresis, thus reducing the damage in the structural members (beams and columns) to a minimum or even to zero. Numerical and experimental investigations on the beam-to-column assemblies within the RFCS FREEDAM project testify to the good seismic performance of the friction device when properly designed. However, within this research project full scale pseudo-dynamic tests will be performed for a better understanding of the influence of such joint on the overall structural behaviour of MRFs. In this paper the results of preliminary numerical simulations are presented to give the first insights on the response of the experimental mockup as well as to validate the accuracy of two software with largely different capabilities. Static pushover and nonlinear dynamic analyses were performed and the results for the benchmark structure (frame equipped with reduced beam section joint) and for the structure equipped with the friction devices are presented

1. Introduction

Steel moment resisting frames (MRFs) designed with full strength joints are structures that are widely used in construction practice [1-4]. Due to their high ductility the design allows for high expected damage in the aftermath of earthquakes [5-24] and this is of course linked to high repair costs. Replacing the traditional plastic hinge dissipation mechanism with a low-damage, friction-based energy dissipation solution [25-27], like the friction device developed for steel beam-to-column joints within the FREEDAM project [28-33], is believed to mitigate the repair costs due to the minimal damage in easily replaceable parts (parts belonging to the friction device).

The friction device proposed by the FREEDAM consortium was subjected to several experimental campaigns. In the preliminary phases, the research was focused on the friction component by means of extensive experimental campaigns on lap-shear specimens [25, 28]. A subsequent phase consisted in the tests on beam-to-column assemblies, considering two geometrical configurations, which proved the effectiveness of the design procedure and the very good seismic performance of the friction devices. The third experimental phase consists in a set of full-scale pseudo-dynamic tests to be carried out on a 2-storey 1-bay mockup equipped alternatively equipped with traditional (e.g. bolted end-plate with dog-bone or reduced beam section - RBS) and friction joints, as shown in figure 1. In order to design the test setup and to provide preliminary characterization of the response of the experimental mockup, finite element (FE) simulations have been carried out.

A secondary aim of this paper is to verify the effectiveness of two software, with largely different capabilities, in the assessment of the structural response. The first set of analyses were performed in

SAP2000, which uses simplified modelling approaches, offering nevertheless a fair level of accuracy of results. The second step was modelling the same structure with a more sophisticated software: ABAQUS 6.14. In this latter case, the model is more refined and can better catch the global and local response. However, the software can be used only by a skilled user, requires more input data and is computational demanding. The description of the mockup and the modelling assumptions are described hereinafter.
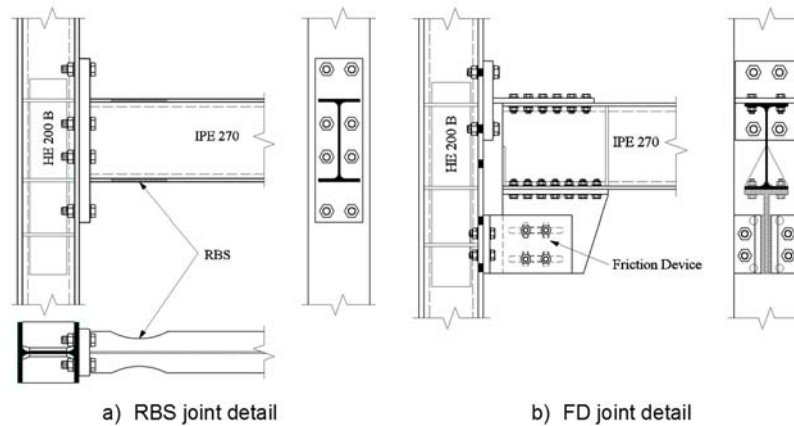

Figure 1. Joint details for the two frame typologies.

2. The Numerical Models: Simplified vs Advanced

The simplified modelling of the two frames (identified by their joint as RBS and FD, respectively) was developed in SAP2000. The members were modelled using linear elements and the experimental conditions, in terms of boundary conditions and loading, were duly set (see figure 2). Rigid offsets were used in the node area to model the higher stiffness. The plastic hinge properties were defined according to the expected behavior i.e. for the RBS the yield bending moment is calculated function of the section and material properties and for the FD the hogging and sagging flexural resistance were defined explicitly based on the expected values calculated analytically and validated experimentally.
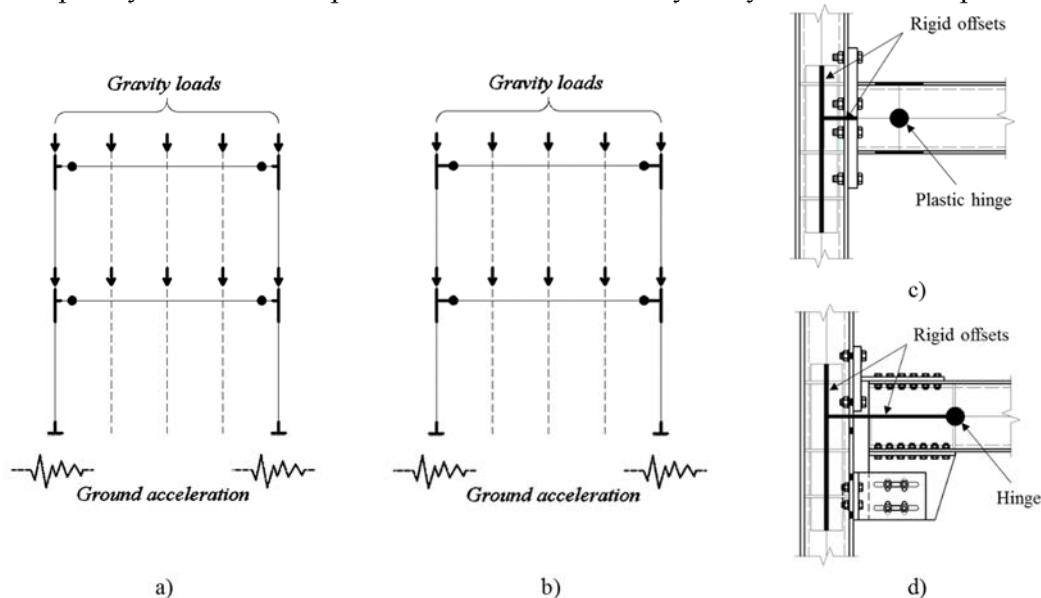

Figure 2. Simplified models in SAP a) RBS model; b) FD model;
c) joint detail for RBS model; d) joint detail for FD model.

The advanced FE model was developed in Abaqus and it included wire elements only in the regions outside of the nodes, which were modelled in detail using 3D solid elements. Figure 3 depicts both the general frame parts and the details of the beam to column and column base joins. The

material was modelled considering the actual post-yield material law obtained experimentally from coupon tests for all steel members. The boundary and loading conditions (gravity loads, bolt preloading, lateral restraints etc.) were assumed as similar as possible to the experimental conditions. C3D8R elements were used for the solid parts and B-31 beam elements are used for the wire elements. The bolts were modelled as shown in [15, 16].
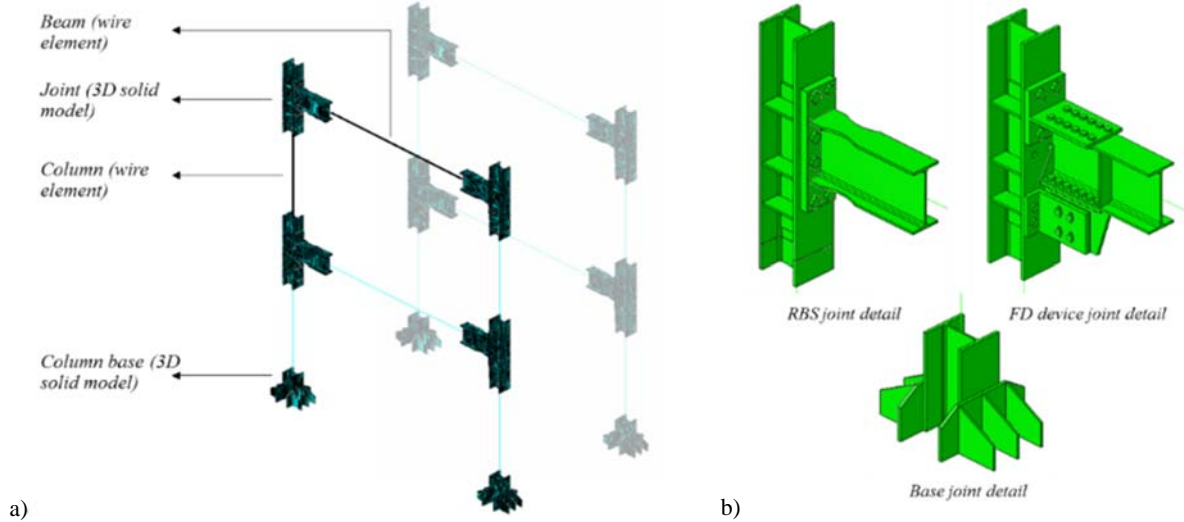

a)   b)

Figure 3. Advanced FE model.

3. Results

The results presented in figure 4 are relative to the two simplified and two advanced models. At a first look it's possible to observe that the monotonic response obtained using the two software is very similar for both frame configurations (figure 4 a and b). The SAP model shows that the maximum base shear for the planar frame is approximately 407kN for the RBS frame and 390 for frame FD. On the other hand, the time history results, evaluated considering an Italian earthquake (Castelnuovo –Assisi Mw: 6) (figure 4 d and e), show that the maximum base shear is underestimated by the simplified model and not achieved at the same time instant in the two models. Furthermore, the simplified model does not capture the residual drifts obvious in the advanced model. The comparison of monotonic and cyclic results of the RBS and FD advanced model (figure 4 c and f) show that the two models exhibit similar behavior, in line with what was the expected and desired response.
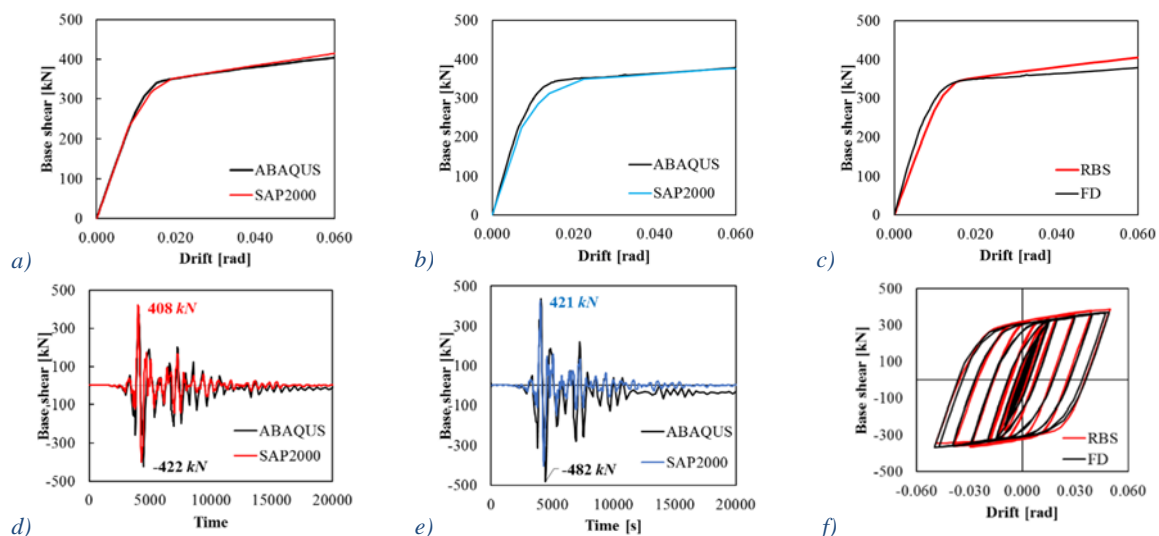

Figure 4. Simplified vs advanced models:
a) SPO for RBS frame b) SPO for FD frame, c) RBS vs FD frame.

4. Conclusions

The simplified model gives a good monotonic prediction of the overall response if compared to ABAQUS model, while the cyclic response underestimates the maximum base shear, overall response and residual drift evaluated with the refined FE model. However, the differences are acceptable and it can be concluded that simplified models can be used to perform demanding analyses and investigate the global response, while the advanced model is useful for the understanding of the local effects.

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