

OPINION PAPER

A call to refocus research goals for the development of seismic optimization methods

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At present, there exist a significant number of optimization methods that are very effective for determining the properties of structures that satisfy a given seismic design or performance objective. This advancement has been possible thanks to a steady pace of development carried out by researchers. Yet, these methods have not been widely adopted by practicing engineers, most of whom still use a traditional iterative procedure for structural design.

This situation has motivated us to ask ourselves if those of us who conduct research in this area are focusing our efforts in the most strategic direction. This document is an open invitation to discuss this issue, with the aim to promote a collective reflection of our present work, in order to set the best directions for future research efforts in this important area.

To start, it is important to state that in our opinion, the ultimate goal of any research in seismic engineering must be to promote the design and construction of better performing and more resilient structures. We believe this goal motivates all research fields of seismic engineering, including, in this case, seismic design optimization. This premise has two implications for optimization-based seismic design procedures: a) these methods must be developed with the motivation of improving the seismic performance of structures, and b) these methods must be evaluated in terms of their ability to fulfill this goal. If existing optimization methods are not actually used by engineers who design structures, as researchers we must question their ability to fulfill these central goals.

Consequently, we need to identify those attributes of seismic optimization methods that are important to fulfill the goal of being useful for designing buildings with better seismic performance. In the authors' opinion, these attributes are three: effectiveness, computational performance, and feasibility.

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For this purpose, we define the effectiveness of a method as the capability of the optimization to produce the intended result in terms of seismic performance. Here, we take performance to mean not only satisfying code-minimum requirements, but also achieving other types of performance objectives (for example, satisfactory resistance against collapse evaluated probabilistically). Measuring a method's effectiveness is a complex task, since it frequently requires the definition of a reference point. Since any building that satisfies the design code can be such point, it is more convenient to establish a comparison between methods. Fortunately, thanks to advances in seismic engineering, like nonlinear analysis and performance-based earthquake engineering, we can now more easily measure the relative effectiveness of various methods, and identify their advantages and shortcomings in this aspect.

The computational performance of a seismic optimization method can be measured as the time needed to solve a problem. Given a concrete problem and the same allocation of computational resources, one method is said to be computationally more efficient than other if it requires less time to find the solution. While there are other parameters associated with computational performance, such as the number of iterations and rate of convergence, these do not have the same relevance in the context of our aforementioned goal.

We refer to feasibility as the degree to which the optimization procedure is easy or convenient to implement, and the ease with which its results can be implemented in seismic designs. Feasibility is related to the level of knowledge and effort required to carry the optimization, as well as engineers' comfort and familiarity with its results. The knowledge required for different types of optimizations is related to their objectives and constraints; for instance, a deterministic based optimization (DBO) with constraints on the nonlinear seismic performance, requires knowledge of optimization techniques, as well as nonlinear dynamic analysis of structures. The effort is measured as the man-hours required to accomplish the design optimization.

The other important aspect related to feasibility is the comfort with the results. This aspect is especially important in structural engineering, since the nature of the profession relies for important reasons on intuition and previous experience. Consequently, a seismic optimization method that produces a design that significantly deviates from current practice will experience resistance from practitioners. Similarly, a highly automated optimization can produce discomfort, since it may neglect engineering experience.

The discussion thus far leads us to conclude that if current seismic design optimization methods are effective – and there are a substantial number of research articles in this and other journals indicating that they are –, but are not used, then they must be lacking in computational performance or feasibility. To investigate this deficiency, it critical to remember who are the potential users of optimization procedures: structural engineers. Seismic optimization methods must have enough computational performance and feasibility, such that they can be used by structural engineers, who are the people responsible for designing structures. Though simple, this conclusion implies that we need to change the focus of our research efforts in seismic optimization methods. Research has yielded enough advancements in the effectiveness, though more will always be welcomed; nevertheless, it is time to concentrate in improving the feasibility and computational performance.

Structural designers generally follow a streamlined process, with important contributions from structural design and analysis software and CAD or BIM. In addition, profit margins in structural engineering offices are often thin. Consequently, the computational performance of seismic optimization methods should not significantly extend the normal time frames of engineering practice. For instance, if the design process of a conventional 5-story building takes four days to complete, an optimization method should not extend the process by more than one day. Though short for research purposes, this time limitation for the optimization process makes sense, especially when we sum the additional time of many design projects.

Computational resources increase every year at an impressive rate, and they become cheaper with time; in addition, they can be outsourced at very convenient rates (e.g. Amazon cloud services), such that if a method cannot achieve enough computational efficiency on mainstream computers, it must have the capability to scale with larger computational resources.

As a result of this possibility, feasibility should become a critical goal in the development of seismic optimization procedures. Ideally, an optimization method must lend itself for implementation within existing CAD and BIM software such as the already existing ACE OCP plugin for SAP/ETABS, which was developed based on research by Lagaros (2014). The integration of optimization procedures within existing tools may also help increase awareness of methods that are available. Admittedly, the quest for these features may result in methods that are less effective than some of the existing ones in the first attempts; but, we must keep in mind that a method intended for use in practice needs only to produce better design results than those achieved by current engineering practice.

Developing seismic optimization methods with such attributes is not an easy task, but that is precisely our challenge: we must produce the next leap forward in structural engineering design, always remembering that the ultimate goal of our efforts must be to help produce better performing, more resilient structures.

REFERENCES

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