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A loophole in the Eurocode 8 allowing for non-conservative seismic design

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ABSTRACT

The prescriptions of the Eurocode 8 (EC8) concerning the static method of seismic analysis may lead to non-conservative design with respect to the more rigorous modal response spectrum analysis. The reason is the unconditioned reference the EC8 makes to the correct value of the fundamental period of vibration of the building. This can produce non-conservative results, especially when the method is applied to buildings that are not regular in plan. The present paper shows how this can happen by referring to the seismic analysis of a series of buildings with different eccentricities between center of mass and center of stiffness. The result should prompt appropriate changes to be introduced in the EC8. The paper also hints at some possible routes to avoid this shortcoming.

1. Introduction

The *dynamic method* and the *lateral force method* are among the most widespread methods of seismic analysis of buildings. The dynamic method is based on the earthquake response spectrum and requires a preliminary analysis of the natural modes of vibration of the structure [1–3]. The lateral force method, on the other hand, models the seismic actions as an appropriate set of horizontal forces acting statically upon the masses of the structure; see e.g. [4–7]. This method is quite often applied in the design of buildings, provided that they are regular enough.

The lateral force method has the advantage over the dynamic method of not requiring any previous modal analysis. The horizontal forces to be applied to each storey of the building are prescribed on the basis of a rough estimate of the fundamental period of vibration of the building itself. The seismic codes of practice provide approximate formulae to evaluate this period, thus eliminating the necessity of a preliminary dynamic analysis. This method is also called the *static method* — a terminology we shall adopt in what follows. It is a practical and widely used method. It can lead, however, to a dangerous underestimation of the seismic actions, even if it is applied within the limits prescribed by many seismic codes, in particular the Eurocode 8 [7]. The present paper will show why.

The gist of the present arguments is the following. Though providing an approximate formula to evaluate the fundamental period of vibration of a building, the EC8 does not exclude the possibility that the static method could also be applied by using the correct value of that period, [7, Sect. 4.3.3.2.2, clause (2)]. The latter, however, may turn out to be much larger than the one provided by the approximate formula. This happens, in particular, in the presence of eccentricity between the stiffness center and the mass center, still within the range of applicability of the method. However, a larger period of vibration almost invariably means a decrease in the intensity of the seismic forces for the structural design. It is quite possible, therefore, that the introduction of the rigorous period of vibration for the approximate one will reduce the values of the design actions. The latter may even become smaller than the ones that would be calculated from the dynamic method. When this happens, the static method ceases to be conservative when compared to the dynamic method. Under these conditions, the seismic code would unwittingly allow a building design method that, in spite of being less reliable than the more rigorous dynamic method, would be economically more convenient. Clearly, this is hardly acceptable.

The EC8 ignores such a shortcoming and leaves the designer free to make use of the correct value of the fundamental period of vibration of the building in the static method. Due to the highly conventional character of that method, however, the period of vibration to be assumed in the design should be conveniently shorter than the actual one, so as to guarantee that the seismic forces are evaluated on the safe side.

In order to substantiate the present claim, it is enough to refer to any ordinary building and show how the static method can actually be less conservative than the dynamic one. This will be done in Section 2, where we shall show that the static method as in EC8 can under-evaluate the maximum seismic effects by amounts that can be more than 20%–25% below the ones obtained from the dynamic method.

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