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COMPARATIVE STUDY OF LINEAR SEISMIC ANALYSIS METHODS ACCORDING TO EUROCODE 8

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Abstract

This paper presents a comparative study of two linear seismic analysis methods according to Eurocode 8 requirements: the equivalent lateral force method and modal response spectrum analysis. A regular reinforced concrete frame structure (Ground + 4 stories) was analyzed using manual calculations and Tower 8 software. The fundamental periods of vibration and base shear forces obtained by both methods were compared. The results show a high level of agreement, while the equivalent lateral force method provides more conservative results due to the assumption of the dominant influence of the fundamental mode of vibration. The analysis highlights the simplicity of this method and the advantages of modal response spectrum analysis in representing structural behavior.

***Keywords**: seismic analysis, Eurocode 8, equivalent lateral force method, modal response spectrum analysis, reinforced concrete frame*

1. INTRODUCTION

Seismic analysis of civil engineering structures is the procedure used to determine the behavior and response of a structure under earthquake loading. This procedure involves developing an appropriate structural model, defining the seismic action, and determining the internal forces and effects that occur within the structural system. During an earthquake, ground displacements and accelerations occur, generating inertial forces within the structure whose magnitude primarily depends on the mass of the building and its dynamic characteristics [1,2].

In modern design practice, seismic analysis of civil engineering structures is most commonly carried out using procedures defined by Eurocode 8. The choice of an appropriate analysis method depends on several factors, including the structural system, the regularity of the building in plan and elevation, the distribution of mass and stiffness, and the required level of analysis accuracy [2].

Linear static analysis, i.e., the equivalent lateral force method, as well as linear dynamic analysis using modal response spectrum analysis, represent the most commonly used procedures for determining the seismic response of structures in accordance with Eurocode 8 requirements. These methods are based on different approaches to modeling the dynamic behavior of structures. The equivalent lateral force method starts from the assumption that the influence of the fundamental mode of vibration is dominant, in which the dynamic action of an earthquake is replaced by equivalent static horizontal forces. In contrast, modal response spectrum analysis takes into account multiple modes of vibration and enables a more detailed representation of structural behavior during seismic action [3].

Although both methods belong to linear procedures, their application often yields different results in terms of forces and displacements [4]. The aim of this paper is to present the basic principles of the equivalent lateral force method and modal response spectrum analysis, along with their comparison using a reinforced concrete frame structure as an example in accordance with Eurocode 8 requirements.

2. LINEAR methods of seismic analysis

2.1. Equivalent lateral force method

The equivalent lateral force method is a linear static method in which the dynamic seismic action is approximated by equivalent horizontal forces distributed along the height of the structure. The basic assumption of the method is that the total seismic response of the structure is predominantly determined by the fundamental mode of vibration [2,3].

According to the requirements of Eurocode 8, the method can be applied to structures where the influence of higher modes of vibration is limited and where the conditions for structural regularity are met. For systems where higher modes have a significant impact on behavior, modal response spectrum analysis is applied [5].

The basic calculation steps of this method include determining the fundamental period of vibration and the design spectral acceleration from the response spectrum, followed by the calculation of the total base shear force and its distribution along the height of the structure [2].

The fundamental period of vibration can be determined using empirical expressions [5]:

$$T_1 = C_t \cdot H^{3/4} \quad (1)$$

where:

C_t - is a coefficient that depends on the structural system,

H- is the height of the structure.

The total base shear force is determined according to the expression [5]:

$$F_b = S_d(T_1) \cdot m \cdot \lambda \quad (2)$$

where:

$S_d(T_1)$ - the ordinate of the design spectrum for the fundamental period,

m - the total seismic mass,

λ - correction factor.

The resulting force is distributed along the height of the structure according to the expression [5]:

$$F_i = F_b \frac{m_i z_i}{\sum m_i z_i} \quad (3)$$

where m_i and z_i are the mass and height of the corresponding story, respectively.

2.2. Modal response spectrum analysis

Modal response spectrum analysis is a linear dynamic method used to determine the seismic response of a structure by taking into account multiple modes of vibration. For each mode of vibration, the vibration period, mode shape, modal mass, and participation factor are determined [2].

Unlike the equivalent lateral force method, which is based primarily on the fundamental mode of vibration, modal response spectrum analysis allows for the inclusion of higher modes that can have a significant impact on the structural response. According to Eurocode 8, the number of modes included in the analysis must ensure a sufficient contribution to the total effective mass of the system. The results obtained for individual modes are combined using appropriate combination rules, most commonly the SRSS or CQC method [2,5].

3. NUMERICAL ANALYSIS AND RESULTS

To compare the two methods, a model of a reinforced concrete frame structure was created. The structure represents a regular multi-story building analyzed using the Tower 8 software.

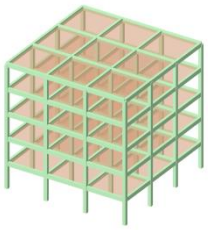


Figure 1. *Numerical model*

Table 1. *Basic structural characteristics*

Parameter	Value
Number of stories	P+4
Story height	3.0 m
Total height	15 m
Columns	40×40 cm
Beams	30×50 cm
Slab	15 cm
Concrete class	C25/30

Seismic analysis was performed in accordance with SRPS EN 1998-1.

For the equivalent lateral force method, a manual calculation of the base shear force and its distribution along the height of the structure was performed. The resulting forces per story are presented in Table 2.

Table 2. *Distribution of seismic forces per story*

Story	$F_i\,[kN]$
5	217.91
4	174.33
3	130.75
2	87.20
1	43.60

Modal response spectrum analysis was performed in Tower 8 using the Type 3 design spectrum in accordance with Eurocode 8. the fundamental period of vibration and the base shear force were calculated. The results obtained using both methods are presented in Table 3.

Table 3. *Comparison of results*

Value	Equivalent lateral force method	Modal response spectrum analysis
Fundamental period of vibration T_i [s]	0.5720	0.5698
Base shear force [kN]	653.74	441.28

4. CONCLUSION

This paper presents two linear seismic analysis methods according to Eurocode 8 requirements: the equivalent lateral force method and modal response spectrum analysis. A comparison of the results obtained through manual calculations and software analysis was performed for a reinforced concrete frame structure.

The fundamental period values obtained using empirical expressions (equivalent lateral force method) and numerical analysis (modal response spectrum analysis) show an exceptionally high degree of agreement, confirming the validity of the applied models. The equivalent lateral force method yielded more conservative results and a higher total base shear force compared to modal response spectrum analysis, which results from the assumption that the fundamental mode of vibration has a dominant influence.

The equivalent lateral force method uses approximate expressions and is designed to be on the side of safety. For regular structures, it provides good results, but because it does not account for the actual deformation distribution and the participation of higher modes in a precise manner, the total base shear force is often overestimated.

Regulations strictly specify the conditions under which the equivalent lateral force method can be used (typically buildings must satisfy height regularity criteria). Because of its conservative nature, engineers often perform modal response spectrum analysis to achieve more economical and realistic element sizing while still satisfying all safety criteria.

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