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# Free Vibration Analysis of a T-Shape Frame

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**Abstract**

This article deals with the free vibration analysis and determination of seismic parameters of a T-Shape frame which consists of a continuous beam and a column connected to each other by means of a semi-rigid Khorjini connection. Firstly, a closed-form solution is proposed and then, a numerical analysis is performed for some comparison and validation purposes. The closed-form solution is developed by solving the frame equations of motion, directly. For this reason, some mathematical techniques such as Fourier transform and the well-known complementary solutions are utilized. Afterwards, the free vibration parameters of the frame are attained. These parameters are also obtained using finite element method as a numerical analysis and it is observed that the results obtained by this approach are completely coincident with the result of closed-form solution. Finally, seismic parameters of the frame and seismic behavior of the semi-rigid Khorjini connection for different cases are investigated and their results are compared.

**Keywords: Free vibration analysis, T-shape frame, semi-rigid Khorjini connection, Euler-Bernoulli beam, Boundary condition**

## 1. INTRODUCTION

The free vibration analysis of beams and frames is an important problem in the structural engineering and many researchers have devoted themselves to the study of this field, with more concentration on the beams [1, 2, 3, 5, 6, 7, 8] in contrast with the frames [4,9]. Moreover, the study of the closed-form solution of vibrating frame structures along with the numerical solution and comparison of these two approaches, in order to examine the accuracy and the precision of the numerical one, such as Finite Element Method (FEM), Boundary Element Methods (BEM), etc., is hardly considered in the literature. Herein, we are not willing to intent on the review of the literature; consequently some of the relevant recent papers will be cited. For example, Kim et al. [1] derived the frequency equations for Euler –Bernoulli beams with general restraints in matrix form by using Fourier series. The problem of free vibrations of a uniform beam with intermediate constraints and ends elastically restrained against rotation and translation had been studied by Albarracin et al. [2]. Also, Li [3] used an alternative discretization scheme based on the Galerkin method, instead of the Fourier method for solving the governing differential equation for beams. As an interesting work on the frame structures, the free vibration of a frame with intermediate constraints and elastic restraints has been investigated by Albarracin et al. [4]. Moreover, ref. [10] is an excellent book about the free vibration analysis of several beams and some frames.

In addition to what mentioned above, investigation about semi-rigid Khorjini connection is performed by some researchers. Hosseini and Hassanzadeh evaluated the performance of semi-rigid Khorjini connection in Bam earthquake in Iran [11]. Also, the behavior of this kind of connections in fire is investigated by Daryan and Bahrampoor [12].

This article deals with the free vibration analysis and determination of seismic parameters of a T-Shape frame which consists of a continuous beam and a column connected to each other by means of a semi-rigid Khorjini connection. The both ends of continuous beam and the end of column are simply supported. The individual members of the frame are assumed to be governed by the transverse vibration theory of an Euler-Bernoulli beam and the semi-rigid Khorjini connection is modeled utilizing a rotational spring. To solve this problem, a closed-form solution is firstly proposed and then, a numerical analysis is performed for some comparison and validation purposes. The closed-form solution is developed by solving the frame equations of motion, directly. For this reason, some mathematical techniques are utilized, such as Fourier transform and the well-known complementary solutions. In this way, some differential equations must be