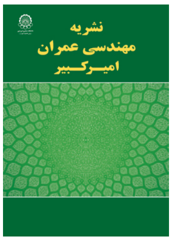


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# Transverse Vibration Analysis of Complicated Truss Arch Bridges Using Continuum Elements

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**ABSTRACT:** Modeling and analysis of complicated truss arch bridges are very time consuming process. In this paper, for more convenient modeling and reduction of analysis time, the complicated truss arch bridges are simulated to the continuum curved beam elements. As a matter of fact, the three dimensional body of a truss bridge is modeled based on the equations governing the out of plane performance of a curved beam. To this end, a new mixed finite element formulation (stiffness-softness) is presented using weighted residual method. In order to verify the accuracy of the present method, the transverse vibration of three truss arch bridges is investigated under a specific time-history. The results are comparable with those obtained from more exact 3D models simulated with SAP 2000 general purpose software, regarding the acceleration and displacement response. Furthermore, in the proposed method the number of elements is significantly less than complicated 3D models, leading to more suited initial design.

## 1- Introduction

Analysis of dynamic response of complicated bridges has drawn attention of many researchers in recent decades [1-6]. Shama et al. [2] studied the North Grand Island Bridge using SAP2000 software. The validity of the modeling was verified using ambient vibration analysis.

Torkamani and Lee [3] investigated the seismic response of Birmingham Bridge using normal mode method. Davis et al. [7] developed the stiffness matrix using the force-displacement relationship. The effect of shear deformation was addressed in the formulation. Yoo and Fehrenbach [8] presented a curved finite element for free vibration analysis of horizontally curved beams. Kang and Yoo [9] and Yoon et al. [10] investigated the out-of-plane dynamic behavior of thin-walled curved beams. They introduced warping effect in their formulations.

During the time, some other issues have been addressed for modeling of the horizontally curved beams including: the effects of transverse shearing force; and rotational and torsional inertia force [11].

The present paper is to simplify the modeling of complicated truss arch bridges using continuum elements. To this end, a new element model is formulated using the mixed finite element method. To verify the validity of the method, three truss arch bridges were analyzed using the present method and SAP2000 software. The results are in good agreement with each other.

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## 2- Methodology

In this paper 3-D model of a complicated truss arch bridge is first simulated to a horizontally curved beam (Figure 1). Then, the transverse seismic response of the simulated curved beam is analyzed using a mixed finite element formulation based on weighted residuals. In this formulation, the transverse displacement, w, the twist, $\phi_z$, the transverse moment, $m_x$, are taken as independent variables [12, 13].

Based on the assumed independent variables, the mixed finite element formulation for transverse seismic response of the curved beam is obtained as [14, 15]:

$$\begin{bmatrix} \chi_{11} & \chi_{12} & \chi_{13} \\ \chi_{21} & \chi_{22} & \chi_{23} \\ \chi_{31} & \chi_{32} & \chi_{33} \end{bmatrix} \begin{Bmatrix} W \\ \phi_z \\ M_x \end{Bmatrix} = \begin{Bmatrix} V_y \\ M_z \\ \phi_x \end{Bmatrix} \tag{1}$$

in which, W, $\phi_z$, $M_x$, are the nodal transverse displacement, the nodal twist, and the nodal transverse moment respectively. Moreover, $V_y$, $M_z$, $\phi_x$, are the nodal shearing force, the nodal torsion, and the nodal slope, respectively. The matrix elements, $\chi_{ij}$, are in the form of the mixed stiffness-softness.

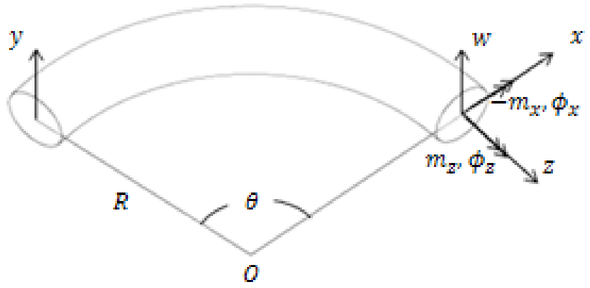


Figure 1. Curved beam model

## 3- Results and Discussion

In order to verify the accuracy of the proposed method, three truss arch bridges as noted in Table 1 were investigated. The bridges were analyzed using the present method based on the continuum model and the 3-D model developed in SAP2000 software. Figure 2 illustrates the bridges modeled with SAP2000. The model dynamic responses were studied under the Tabas earthquake in both methods. The results are given in Table 2. As observed, the results obtained from the present method correlate well to those from 3-D models.

## 4- Conclusions

A simplified method was developed to analyze dynamic response of truss arch bridges subjected to transverse seismic load. To this end, a 3D truss arch bridge was replaced with the curved beam model. Then, dynamic analysis of curved beams was formulated using mixed finite element. To verify the validity of the method, the results obtained from the present method were compared with those resulted from SAP2000 software. The comparison confirmed the accuracy of the proposed method in estimation of dynamic response of truss arch bridges.

Table . Geometrical specifications of truss arch bridges

| Model | Geometrical specifications | | | Elem. section | |
|---|---|---|---|---|---|
| | Length (m) | Height (m) | Width (m) | Pinned Elem. | Perimeter Elem. |
| 1 | 192 | 50 | 8 | 2UNP140 | HEB180 |
| 2 | 63 | 15 | 4 | 2UNP140 | 2IPB260 |
| 3 | 48 | 8 | 4 | 2UNP400 | 2IPB700 |

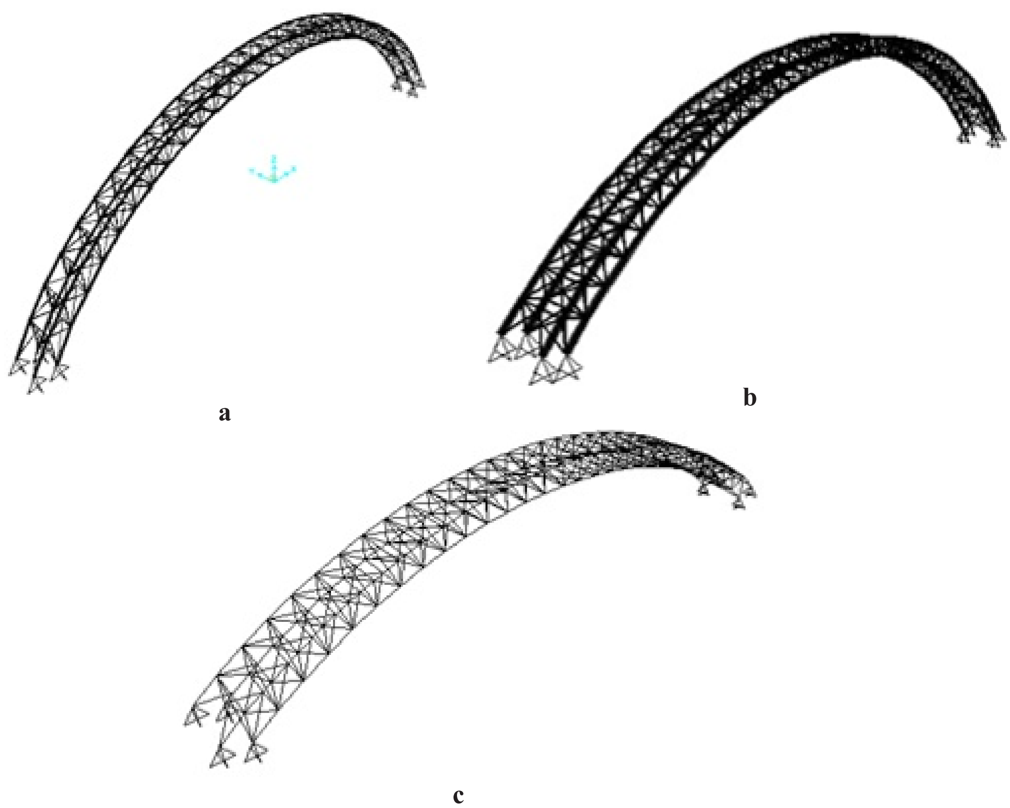


Figure 2. Truss arch bridges modeled in SAP2000; (a) Model 1; (b) Model 2; Model 3

**Table 2. Results of time-history analysis**

| Model | Proposed method | | | Software Frame method) SAP2000) | | | Errors | |
|---|---|---|---|---|---|---|---|---|
| | No. elem. | Max. dis (m) | Max. accel. ($m/s^2$) | No. elem. | Max. dis (m) | Max. accel. ($m/s^2$) | Error in accel. (%) | Error in dis. (%) |
| 1 | 8 | 0.0229 | 1.4490 | 500 | 0.0243 | 1.5341 | 5.55 | 5.76 |
| 2 | 14 | 0.0033 | 0.9560 | 640 | 0.0031 | 0.8853 | 7.99 | 6.45 |
| 3 | 10 | 0.0013 | 0.5016 | 460 | 0.00137 | 0.5118 | 1.99 | 5.10 |

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