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Modal testing and finite element model calibration of an arch type steel footbridge

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Abstract. In recent decades there has been a trend towards improved mechanical characteristics of materials used in footbridge construction. It has enabled engineers to design lighter, slender and more aesthetic structures. As a result of these construction trends, many footbridges have become more susceptible to vibrations when subjected to dynamic loads. In addition to this, some inherit modelling uncertainties related to a lack of information on the as-built structure, such as boundary conditions, material properties, and the effects of non-structural elements make difficult to evaluate modal properties of footbridges, analytically. For these purposes, modal testing of footbridges is used to rectify these problems after construction. This paper describes an arch type steel footbridge, its analytical modelling, modal testing and finite element model calibration. A modern steel footbridge which has arch type structural system and located on the Karadeniz coast road in Trabzon, Turkey is selected as an application. An analytical modal analysis is performed on the developed 3D finite element model of footbridge to provide the analytical frequencies and mode shapes. The field ambient vibration tests on the footbridge deck under natural excitation such as human walking and traffic loads are conducted. The output-only modal parameter identification is carried out by using the peak picking of the average normalized power spectral densities in the frequency domain and stochastic subspace identification in the time domain, and dynamic characteristics such as natural frequencies mode shapes and damping ratios are determined. The finite element model of footbridge is calibrated to minimize the differences between analytically and experimentally estimated modal properties by changing some uncertain modelling parameters such as material properties. At the end of the study, maximum differences in the natural frequencies are reduced from 22% to only %5 and good agreement is found between analytical and experimental dynamic characteristics such as natural frequencies, mode shapes by model calibration.

Keywords: dynamic characteristics; finite element model calibration; footbridge; modal testing; peak picking; stochastic subspace identification.

1. Introduction

Footbridges are generally situated to allow pedestrians to cross water or railways in areas where there are no nearby roads to necessitate a road bridge, and also across busy roads to let pedestrians cross safely without slowing down the traffic. There are several different designs of footbridges recently constructed, from the main types of constructions such as a construction with lateral beams, a steel box-

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girder construction with orthotropic deck, a construction with a ribbed slab, a bow-string arch with orthotropic deck, a suspended construction with one steel mast, a steel lattice arch and a cable-stayed construction (Setra 2006).

It is generally expected that finite element models based on technical design data and engineering judgments can yield reliable simulation for both the static and dynamic behaviour of footbridges. However, because of modelling uncertainties such as stiffness of supports and non-structural elements, material properties and so on as well as inevitable differences between the properties of the designed and as-built structure, these finite element models often cannot predict natural frequencies and mode shapes with the required level of accuracy. This raises the need for verification of the finite element models of footbridges after their construction. For this purpose, modal testing is nowadays used commonly. The aim of modal testing is to determine as-built natural frequencies, mode shapes and damping ratios. These are especially important when they are required to further study of behaviour of footbridge. For example, the modal damping, a very important dynamic parameter which governs the footbridge dynamic response near resonance, varies from structure to structure and can only be determined experimentally after the particular structure is built (Zivanovic *et al.* 2006).

There are two basically different methods available to experimentally identify the dynamic system parameters of a structure (of any kind, including footbridges): Experimental Modal Analysis and Operational Modal Analysis (Cantieni 2004). In the Experimental Modal Analysis, the structure is excited by known input force (such as impulse hammers, drop weights and electrodynamics shakers) and response of the structure is measured. In the Operational Modal Analysis, the structure is excited by unknown input force (ambient vibrations such as traffic load, wind and wave) and response of the structure is measured. Some heavy forced excitations become very expensive and sometimes may cause the possible damage to the structure. But, ambient excitations such as traffic, wave, wind, earthquake and their combination are environmental or natural excitations. Therefore, the system identification techniques through ambient vibration measurements become very attractive. In this case only response data of ambient vibrations are measurable while actual loading conditions are unknown. A system identification procedure will therefore need to base itself on output-only data (Roeck and Peeters 2000). In this study, Operational Modal Analysis procedure is used to determine the dynamic characteristics of arch type steel footbridges.

Once the modal dynamic properties of a footbridge (mainly natural frequencies and mode shapes) are identified experimentally and the level of error introduced by the initially developed finite element models is identified, their drawbacks in the finite element modelling can be found and the initial finite element model can be corrected. This procedure is called finite element model calibration, and can be considered as an attempt to use the best features from both the experimental and analytical models (Modak *et al.* 2002).

The first part of this paper reviews briefly the existing literature concerning the analytical and experimental investigations of civil engineering structures and especially footbridges. This is followed by finite element model calibration procedures. After then, the formulation of Peak Picking (PP) and Stochastic Subspace Identification (SSI) methods which are used to extract of modal parameters experimentally is given with detail. Then, the arch type steel footbridge is described. Also, the initial finite element model and main assumptions made during its development are presented. After this, modal testing of footbridge in frequency and time domain using PP and SSI methods are described, together with an ambient vibration testing exercise. Then, experimental modal properties compared with the numerical results. Finally, the finite element model is manually calibration and key results of this interesting exercise are discussed.

2. Background review

2.1 Modal Testing

Modal testing is one of the most popular techniques for studying the behaviour of a structure through a number of natural frequencies and mode shapes. Various methods, including time and frequency domain, are available for extracting modal information from the dynamic response of a structure and corresponding input excitation. The process of establishing the characteristics of a system from an experimental model is known as system identification (Ljung 1987).

Modal testing of structures is not a recent practice, and many studies have been carried out in the past. Modal testing was originally developed in the more advanced mechanical and aerospace engineering disciplines (Ewins 1984, Juang 1994, Maia and Silva 1997), where modal parameter identification was based on both input and output measurements. After the modal testing procedure transferred the civil engineering, this procedure was successfully implemented on different type of civil engineering structures such as bridge (Zivanovic *et al.* 2006, Deger *et al.*1996, Rainer and Pernica 1979, Brownjohn *et al.* 1992, Brownjohn 1997, Chang *et al.* 2001, Bayraktar *et al.* 2007, Abdel-Ghaffar 1978, Buckland *et al.* 1979), building (Sortis *et al.* 2005, Ventura *et al.* 2002), historic masonry tower (Gentile and Saisi 2007), stadium (Reynolds *et al.* 2004), reactor building (Ceballos *et al.* 1998), dam (Zhou *et al.* 2000), silo (Dooms *et al.* 2007) and minaret (Bayraktar *et al.* 2007).

Although a lot of studies can be achieved for civil engineering structure, there are only a few articles related to both vibration testing and finite element modelling specifically concerned to footbridges. The first detail studies about modal testing of footbridges were carried out by the UK Transport and Road Research Laboratory in the 1970-1980 (Leonard and Eyre 1975, Eyre and Tilly 1997, Leonard 1974). In the last two decades, a number of authors have started to pay more attention to provide complete data acquisition parameters in their work. Together with this trend some work discussing correlation between modal testing and finite element model results of footbridge has also emerged (Deger *et al.* 1996, Brownjohn 1997, Cantieni and Pietrzko 1993, Pavic and Reynolds 2002, Morse and Huston 1993, Brownjohn *et al.* 1994, Pavic *et al.* 1998).

2.2 Finite element model calibration

In modern analysis of structures, much effort is devoted to the derivation of accurate models. These accurate models are used in many applications of civil engineering structures like damage detection, health monitoring, structural control, structural evaluation, and assessment. In the development of finite element models of structures, it is usual to make simplifying assumptions. The finite element model of a structure is constructed on the basis of highly idealized engineering blueprints and designs that may or may not truly represent all the physical aspects of an actual structure. When field dynamic tests are performed to validate the analytical model commonly natural frequencies and mode shapes, do not coincide with the expected results from the analytical model. These discrepancies originate from the uncertainties in simplifying assumptions of structural geometry, materials, as well as inaccurate boundary conditions. The problem of how to modify the analytical model from the dynamic measurements is known as the model calibration in structural dynamics (Jaishi and Ren 2005). The main purpose of the model calibration procedure is to minimize the differences between the analytically and experimentally obtained modal properties by changing uncertainty parameters such as material properties, boundary conditions.

The calibration process typically consists of manual tuning and then automatic model calibration using some specialised software. The manual tuning involves manual changes of the model geometry and modelling parameters by trial and error, guided by engineering judgement. The aim of this is to bring the numerical model closer to the experimental one (Zivanovic *et al.* 2007). In this study, the manual tuning procedure is used for finite element model calibration.

Over the last decade, there have been several attempts to transfer the calibration technology from the mechanical and aerospace engineering to civil structural engineering. Although the whole is more difficult to implement in civil engineering, some successful examples of calibration in civil engineering can be seen for bridges (Zhang *et al.* 2001, Bayraktar *et al.* 2007), buildings (Lord *et al.* 2004), minarets (Bayraktar *et al.* 2007) and high-rise structures (Wu and Li 2004). Besides these studies, there are only a few papers exist related to both modal testing, finite element modelling and calibration of footbridges (Zivanovic *et al.* 2006, Ravic *et al.* (1998), Zivanovic *et al.* 2007, Bayraktar *et al.* 2007).

In addition to these, well presented review of modal testing methods for bridges explaining their advantages and limitations were presented by Salawu and Williams (1995). Also, well presented review of studies about footbridge was presented by Zivanovic *et al.* (2005). Considering the studies about footbridges, it is seen clearly that there are no enough study related to modal testing and finite element model calibration of footbridges especially arch type steel footbridges. For this reason, modal testing and finite element model calibration of an arch type steel footbridge is studied with detail in this paper.

3. Theory of modal parameters identification techniques

Ambient excitation does not lend itself to Frequency Response Function (FRFs) or Impulse Response Function (IRFs) calculations because the input force is not measured in an ambient vibration test. Therefore, a modal identification procedure will need to base itself on output-only data (Ren *et al.* 2004). There have been several modal parameter identification techniques available which are developed by improvements in computing capacity and signal processing techniques. These techniques include the Peak Picking (PP) method from the Power Spectral Densities (PSDs) (Bendat and Piersol 1993), Auto Regressive Moving Average (ARMA) model based on discrete-time data (Andersen *et al.* 1996), natural excitation technique (NExT) (James *et al.* 1995), Stochastic Subspace Identification methods (SSI) (Van overschee and Moor 1996, Peeters and De Roeck, 1999) and maximum likelihood frequency domain methods (Hermans *et al.* 1998). The mathematical background of nearly all these methods is quite similar, but a few different parts are available in implementation aspects such as data reduction, type of equation solvers and sequence of matrix operations. In this study, two different methods, which are rather simple Peak Picking (PP) method in the frequency domain and the Stochastic Subspace Identification (SSI) method in the time domain, are used for modal parameter extraction.

4. Description of the footbridge

The investigated arch type footbridge is located in a heavy traffic area in Trabzon, Turkey, and has a main span of 35 m. The footbridge operates as part of a pedestrian public footpath. This bridge was originally designed by MAPA Engineers, Inc. in 2006 (MAPA 2007). Fig. 1 shows the some views of the arch type footbridge. General arrangement drawings of the entire bridge are shown in Fig. 2.

The superstructure of the footbridge consists of the steel tubes, vertical and lateral load carrying systems, stairs, piers, and the deck system. The arch span consists of two curved steel tubes, 12 horizontal and 8 diagonally braced members. The 16 main suspended steel pipes (8 on one side) are vertically attached on both sides of the arch and the floor system. The deck of footbridge is suspended from a mast consisting of two curved steel tubes (Figs. 1 and 2). The deck is made of a composite platform (granite, alum, steel, sheet iron and carrier beam) surrounding by steel frame. The deck is 3,3 m wide and 80 mm constant thickness. Along its whole length, the curved pipe girder and deck are stiffened by horizontal brace members (Fig. 2). Horizontal and diagonal supporters are placed under the composite deck. Both edge of the footbridge, 45 stairs are placed. There are two piers consisted of vertical and diagonal members under the middle of the stairs.

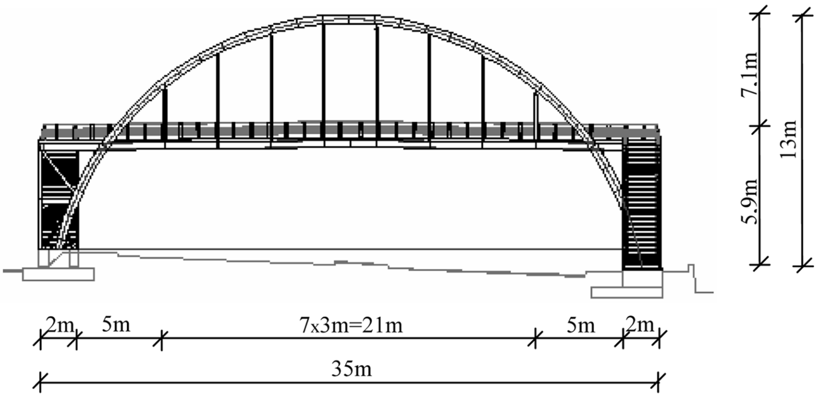
5. Finite element modelling

To obtain the dynamic characteristics such as natural frequencies and mode shapes of the bridge, an initial finite element model is developed with the geometry and structural properties obtained from the design drawings. The term “initial” is used to suggest that the finite element model could be inaccurate due to various modelling and parametric uncertainties and that the model is the basis for the model calibration.

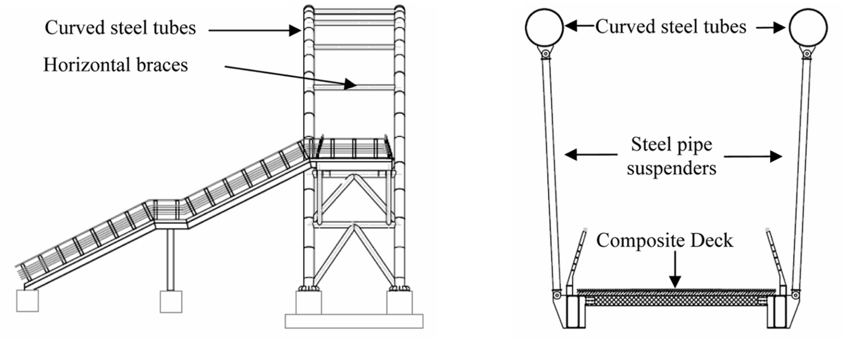
Three dimensional (3D) linear elastic finite element model (Fig. 3) of the arch type footbridge was constructed using the software SAP2000 (SAP 2000 integrated 1998). This program can be used for linear and non-linear, static and dynamic analyses of a 3D model of the structure. In this paper, the program was used to determine the dynamic characteristics such as fundamental frequencies and the corresponding mode shapes of structure, based on its physical and mechanical properties.

The selected footbridge was modelled as a space frame structure with 3D prismatic beam elements

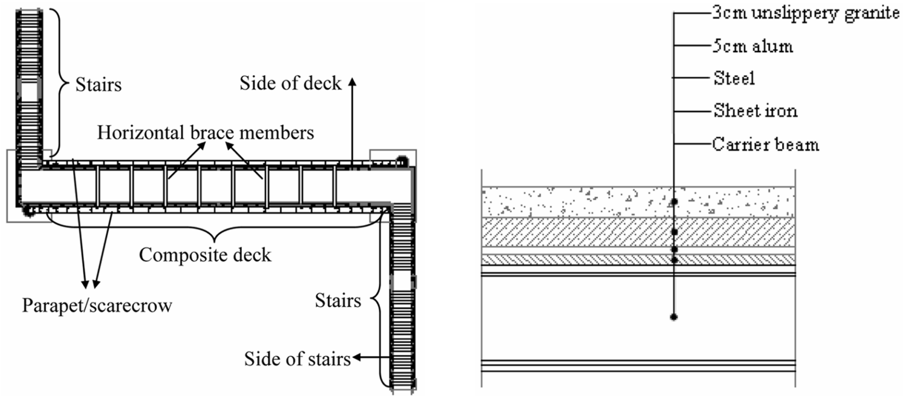
Fig. 1 Some views of the arch type footbridge



a) Front view of footbridge



b) The side views of the footbridge c) A typical cross-section of the footbridge



d) The plan view of the footbridge e) Cross section of composite deck

Fig. 2 General arrangements drawing of the footbridge (MAPA 2007)

which have two end nodes and each end node has six degrees of freedom: three translations along the global axes and three rotations about its axes. The deflection of the structural model was governed by the displacements of the joints; and different connections and supports are simulated by applying corresponding end releases and joint restraints. The aim was to construct a detailed model which would

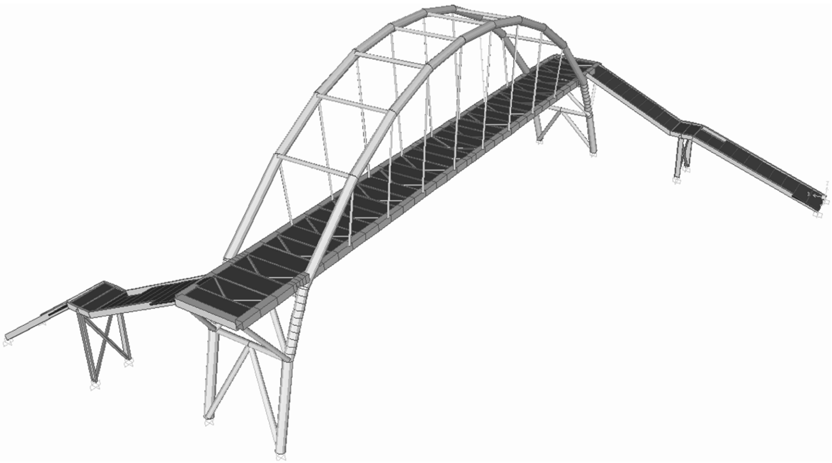


Fig. 3 3D finite element model of the footbridge.

be able to simulate the dynamic behaviour of the structure as well as possible. The key modelling assumptions are as follows:

√ The main steel pipe girders and columns and its transverse stiffeners were modelled using 3D beam elements.
√ The composite steel–concrete deck was modelled using shell elements.
√ The supports of steel arch were modelled as fully fixed.
√ Supports at both ends of the suspenders were modelled as pinned.
√ The members of the bridge frame are modelled as rigidly connected together at the intersection points.

The values of the material properties used in analyses of the footbridge are given in Table 1. The cross section properties of elements are given in Table 2.

Natural frequencies and corresponding vibration modes are important dynamic properties and have significant effect on the dynamic performance of structures. Footbridges always have four main types of vibration modes: lateral, torsional, vertical and longitudinal modes. A total of 25 natural frequencies of the footbridge are attained which range between 2,39 and 21,76 Hz. The six vibration mode of the footbridge as a whole and deck are shown in Fig. 4.

6. Ambient vibration testing and modal identification

The equipment used for the measurement includes 4 tri-axial and 1 uni-axial accelerometers, 17-channel data acquisition system, approximately 100 m tri-axial and 30 m uni-axial signal cables. To identify the mode shapes and natural frequencies of footbridge, structural responses at sufficient

Table 1 Material properties used in analyses of the footbridge

Material	Modulus of Elasticity (N/m^2)	Poisson's Ratio	Mass per unit Vol. (kg/m^3)
Steel	2,000E11	0,3	7900
Concrete	2,482E10	0,2	2403

Table 2 Cross sections of elements used modelling of the footbridge

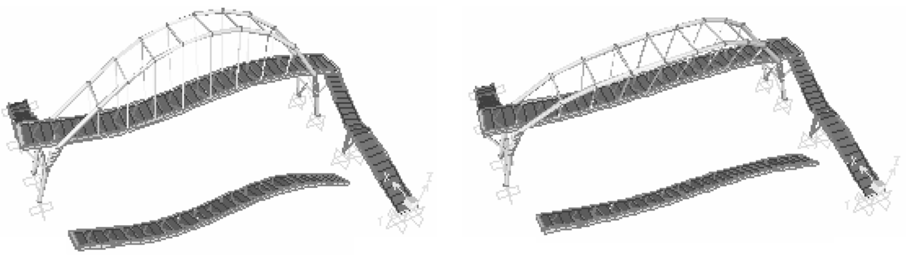
Cross-sectional properties	Element type	Dimension	Number
Curved steel tubes	Steel pipe	Diameter: 47,5 cm, Thickness: 12 mm	2
Steel pipe suspended	Steel pipe	Diameter: 11,4 cm, Thickness: 4,5 mm	16
Horizontal braces	Steel pipe	Diameter: 21,9 cm, Thickness: 5 mm	10
Horizontal braces	Steel pipe	Diameter: 32,3 cm, Thickness: 10 mm	2
Diagonal braces	Steel pipe	Diameter: 27,3 cm, Thickness: 8 mm	8
Deck	Concrete	Thickness: 8 cm	-
Side of deck	[] profile	Depth: 37 cm, Flange thickness: 15 mm Width: 35 cm, Web thickness: 10 mm	Along the side of deck
Stairs	Concrete	Thickness: 8 cm	90 (total)
Side of stairs	[profile	Depth: 30 cm, Flange thickness: 16 mm Width: 10 cm, Web thickness: 10 mm	Along the side of stairs
Supporter (horizontal) under the deck	I profile	Height: 16 cm, Web thickness: 6,3 mm Top and bottom weight: 7,4 cm Top and bottom thickness: 9,5 mm	40
Supporter (diagonal) Under the deck	L profile	Horizontal and vertical leg: 7 cm Horizontal and vertical thickness: 7 mm	36
Piers (vertical)	[profile	Depth: 30 cm, Flange thickness: 16 mm Width: 10 cm, Web thickness: 10 mm	4 (under stairs)
Piers (diagonal)	π profile	Depth: 10 cm, Width: 20 cm Vertical and horizontal thickness: 10 mm	4 (under stairs)

location on the deck in the vertical, lateral and transversal direction is obtained. Accelerometer location in the 3D schematic view and footbridge deck is given in Fig. 5. The tests were conducted on three test setups. In the first test setup the accelerometers are placed at the corner of the footbridge deck as a point number 1, 4, 5 and 8 in Fig. 5. In the second setup the accelerometers are placed at the one side of the footbridge as a point number 1, 2, 3 and 4 in Fig. 5. Since the intended number of measurements was larger than the number of channels and sensors available, measurements are performed in two steps in the third test setup. In the first step, accelerometers are placed at 1, 2, 5 and 6 points and in the second step accelerometers are placed at 3, 4, 7and 8 points in Fig. 5. The signals in the second setup are incorporated using a reference accelerometer located in the 9 point.

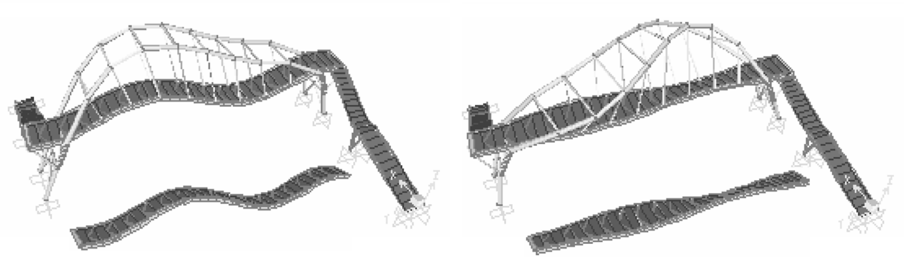
The responses of the footbridge deck were measured by using B&K 4506 type tri-axial accelerometers. The signals were acquired in the B&K 3560 type data acquisition system and then transferred into the PULSE Lapshop software (Fig. 6). For parameter estimation from the Ambient Vibration System (AVS) data, the Operational Modal Analysis software (OMA 2006) was used. The ambient vibration tests were conducted under environmental loads such as human walking and traffic.

The modal identification was performed using a technique of modal extraction in the frequency domain named as enhanced frequency domain decomposition (EFDD) which is extension of the Basic Frequency Domain technique, often called the Peak Picking (PP) and in the time domain named as Stochastic Subspace Identification (SSI). These techniques provide estimating not only the natural frequencies and mode shapes but also modal damping ratios.

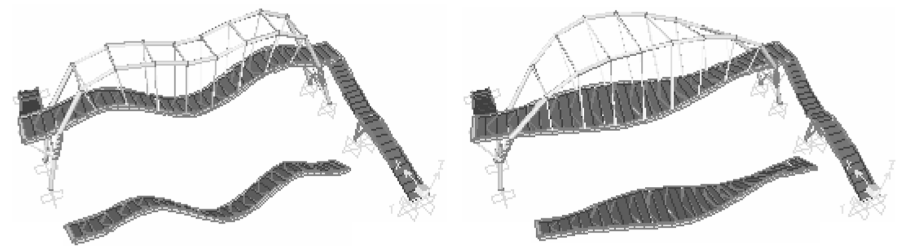
The EFDD technique is initially based on the fact that the Frequency Response Function (FRFs) reaches an extreme approximately at the natural frequencies. In the context of ambient vibration measurements, the FRFs are replaced by auto power spectrum of the ambient vibration responses and



1st Vertical Mode Shape (f= 2,39 Hz) 1st Torsional Mode Shape (f= 2,50 Hz)



2nd Vertical Mode Shape (f= 5,52 Hz) 2nd Torsional Mode Shape (f= 5,93 Hz)



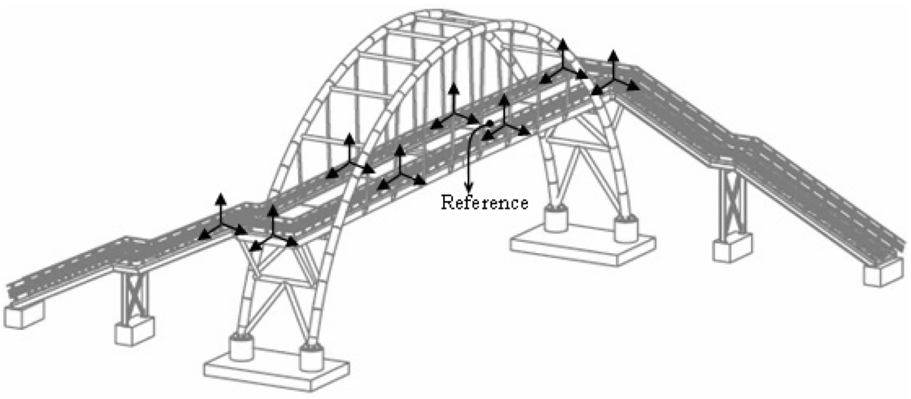
3rd Vertical Mode Shape (f= 7,63 Hz) 3rd Torsional Mode Shape (f= 7,65 Hz)

Fig. 4 Analytically identified mode shapes of the footbridge as a whole and deck.

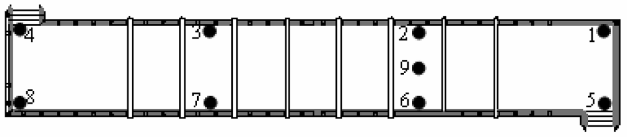
the natural frequencies are simply determined by observing the peaks of the Averaged Normalized Power Spectral Densities (ANPSDs) (Ren and Zatar 2004). Mode shapes can be obtained from the corresponding singular vectors. To estimate modal damping ratios, the singular values near the peak with corresponding singular vector having modal assurance criteria (MAC) higher than a MAC rejection level are transferred back to time domain through inverse fast fourier transform (FFT), which is an approximated correlation function of the equivalent single degrees of freedom (SDOF) system. From the free decay function of the SDOF system, the damping ratio can be calculated by the logarithmic decrement technique. The SSI method, which directly works with time data, was applied to the re-sampled data. One of the advantages of the SSI method is that stabilization diagrams that aid with modal selection may be effectively constructed.

Modal parameters and stabilization diagrams attained from vibration signal using EFDD and SSI techniques are shown in Figs. 7~10.

The first six mode shapes obtained from experimental modal analyses are given in Fig. 11. It can be seen from Figs. 4 and 9 that there is a good agreement between the mode shapes in experimental and analytical modal analyses. Identified frequencies from both methods and corresponding damping ratios



a) 3D schematic view



b) Footbridge deck

Fig. 5 Accelerometer locations in the footbridge

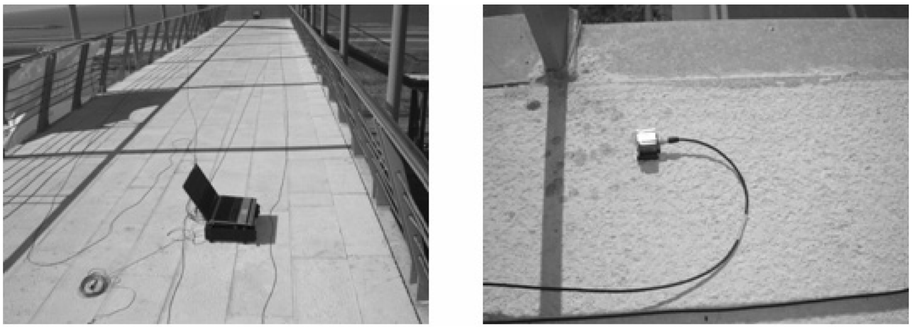


Fig. 6 The pictures from the ambient vibration test

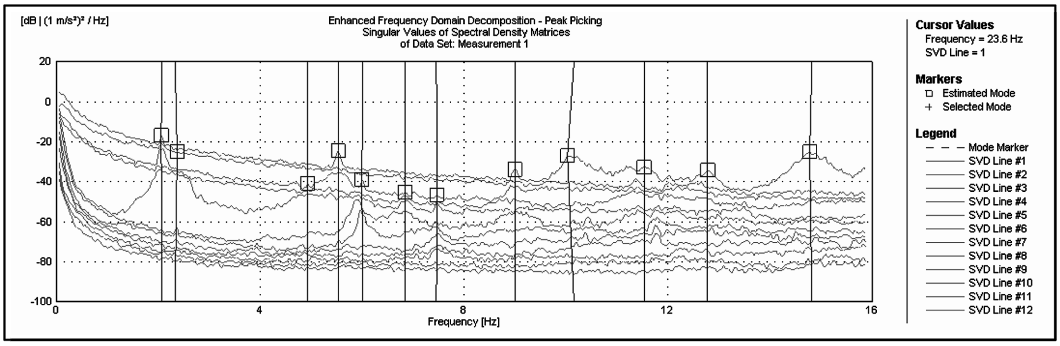


Fig. 7 Modal parameters attained from EFDD technique

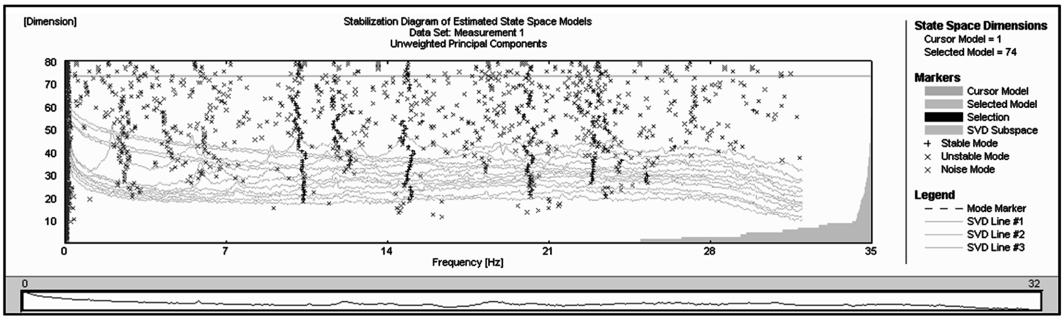


Fig. 8 Stabilization diagram of first setup

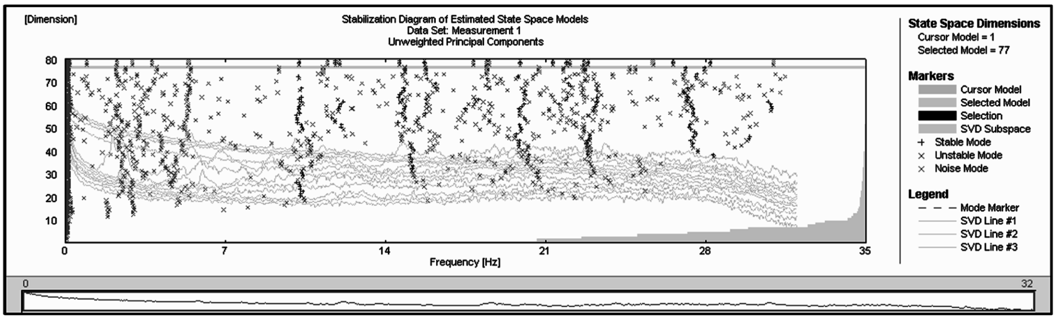
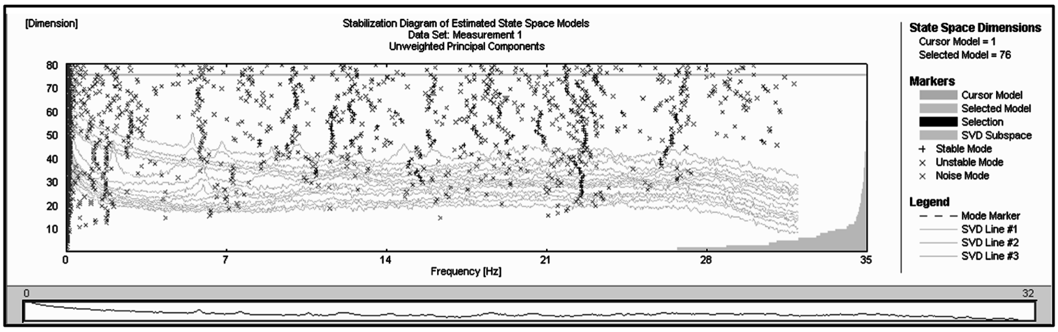
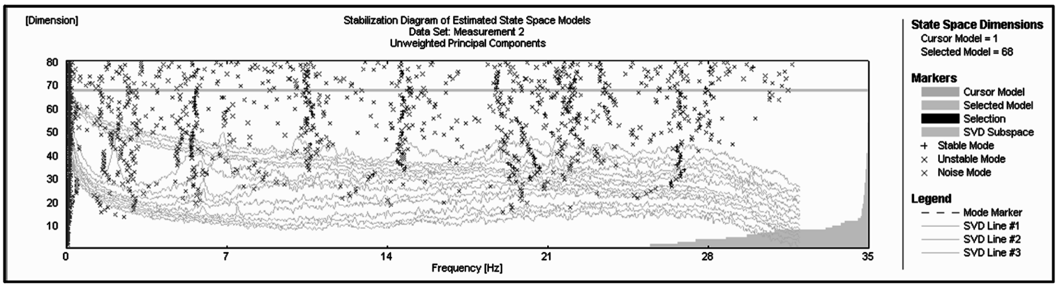


Fig. 9 Stabilization diagram of second setup

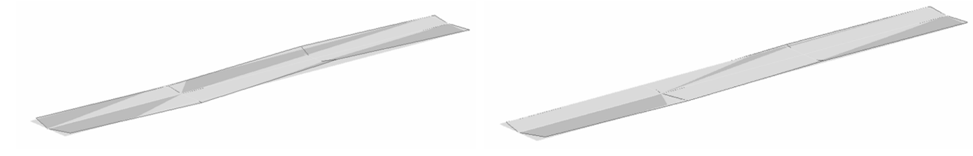


a) First measurement

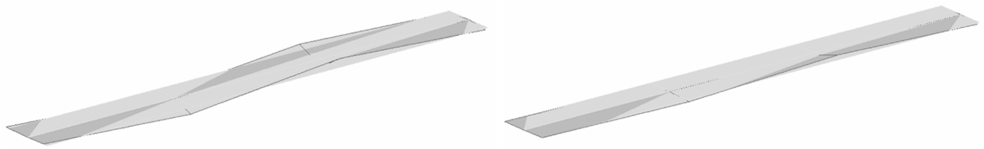


b) Second measurement

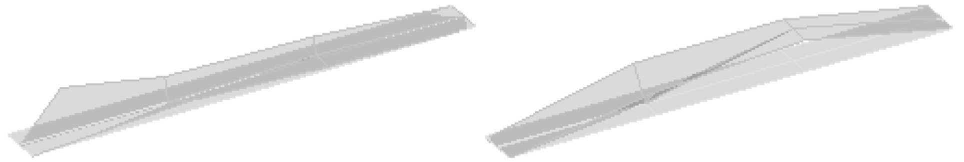
Fig. 10 Stabilization diagrams of third setup



1st Vertical Mode Shape (f= 2,08 Hz) 1st Torsional Mode Shape (f= 2,34 Hz)



2nd Vertical Mode Shape (f= 4,78 Hz) 2nd Torsional Mode Shape (f= 5,53 Hz)



3rd Vertical Mode Shape (f= 6,01 Hz) 3rd Torsional Mode Shape (f= 6,67 Hz)

Fig. 11 Experimentally identified mode shapes

Table 3 Analytical and experimental modal parameters

Frequency Number	Analytical Frequencies (Hz)	Experimental		
		Frequencies (Hz) PP	Frequencies (Hz) SSI	Damping Ratios (%)
1	2,39	2,08	1,90	1,22
2	2,50	2,34	2,40	2,82
3	5,52	4,78	4,70	0,37
4	5,93	5,53	5,50	0,84
5	7,63	6,01	5,80	0,40
6	7,65	6,67	6,70	0,26

attained from Experimental Modal Analyses are summarized in Table 3.

It can be seen from the results of Experimental Modal Analyses that the lowest vibration frequency of the footbridge deck is in the range of 1,9-2,1 Hz, which is the frequency region of normal human walking (Bachmann *et al.* 1995). Although detailed FE model was developed based on the design data available and engineering judgement, some of the measured natural frequencies of the footbridge were different from experimental results.

7. Finite element model calibration

It can be seen from Table 3 that there are some differences between results obtained from analytical and experimental modal analyses. It is thought that these differences come from some uncertainties in the structural geometry, material properties and boundary conditions. For that reasons, the finite element model of the footbridge must be calibrated. In the finite element model of footbridge is calibrated by changing the material properties. Frequency values obtained from analytical and experimental modal analyses after the model calibration of the finite element model of the footbridge are given in Table 4. When Table 4 is examined, there is good harmony between analytical and experimental results after the model calibration of the finite element of the footbridge.

Changing in material properties of structural elements for model calibration of the footbridge is given in Table 5. Considering the experimental and analytical mode shapes of the footbridge after the model calibration a good agreement is found which are similar to Fig. 11.

Table 4 Experimental and analytical frequencies of the calibrated model

Frequency Number	Analytical Frequencies (Hz)	Calibrated Analytical Frequencies (Hz)	Experimental	
			Frequencies (Hz) PP	Frequencies (Hz) SSI
1	2,39	2,09	2,08	1,90
2	2,50	2,34	2,34	2,40
3	5,52	4,77	4,78	4,70
4	5,93	5,53	5,53	5,50
5	7,63	6,47	6,01	5,80
6	7,65	6,63	6,67	6,70

Table 5 Changing in material properties of structural elements for model calibration

Cross-sectional properties	Before the Finite Element Model Calibration		After the Finite Element Model Calibration	
	Modulus of Elasticity (N/m^2)	Mass per unit Volume (kg/m^3)	Modulus of Elasticity (N/m^2)	Mass per unit Volume (kg/m^3)
Curved steel tubes	2,000E11	7900	1,570E11	7000
Steel pipe suspended	2,000E11	7900	1,570E11	7000
Horizontal braces	2,000E11	7900	1,570E11	7000
Diagonal braces	2,000E11	7900	1,570E11	7000
Deck	2,482E10	2403	1,600E10	2403
Side of deck	2,000E11	7900	1,500E11	7900
Stairs	2,482E10	2403	1,600E10	2403
Side of stairs	2,000E11	7900	1,500E11	7900
Supporter (horizontal) under the deck	2,000E11	7900	1,500E11	7900
Supporter (diagonal) under the deck	2,000E11	7900	1,500E11	7900
Piers (vertical) under the stairs	2,000E11	7900	1,500E11	7900
Piers (diagonal) under the stairs	2,000E11	7900	1,500E11	7900

8. Conclusions

In this paper, analytical modelling, modal testing and finite element model calibration of an arch type steel footbridge located in Trabzon, Turkey, was presented. 3D finite element model of the footbridge was developed using SAP2000 program considering the design data and modal parameters such as frequencies and mode shapes were determined. The field ambient vibration testing was conducted under the natural excitation on the footbridge. Two complementary modal parameter identification methods were implemented to accurately extract the dynamic characteristics. Comparison of the analytical and experimental modal analyse results, some differences were seen. For this reason, the finite element model of the footbridge is calibrated to minimize the differences between analytically and experimentally estimated modal properties by changing some uncertain modelling parameters such as material properties. Comparing the result of study, the following observation can be made:

1. From the finite element model of the footbridge, a total of 25 natural frequencies were attained analytically, which range between 2,39 and 21,76 Hz. Considering the first six mode shapes, these modes can be classified into vertical and torsional modes.
2. The ambient vibration testing was conducted under the natural excitation on the footbridge for accurately extract the dynamic characteristics using PP and SSI techniques. Good agreement of identified frequencies was found between PP and SSI techniques.
3. When comparing the analytical and experimental results, it was clearly seen that there were some differences in the both results, and analytical frequencies were bigger than those of the experimental.
4. To eliminate differences, finite element model of the footbridge was calibrated by trial and error of material properties and the maximum difference in the natural frequencies was reduced from 22% to only %5.
5. After the model calibration, there were good agreement between the frequencies and mode shapes obtained from the calibrated model of the footbridge and experimental measurements.

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