An Observer Eigensystem Realization Algorithm for Time Domain Structure Identification based on Earthquake Record

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Introduction

This paper presents a methodology to identify dynamic characteristics of linear structure on modal-base, using earthquake induced time histories of structural response. The methodology is based on the Observer Eigensystem Realization Algorithm (OERA) approach to perform identification of structural system using general input-output set via Markov parameters. The proposed methodology is applied to identify structural properties of Matsunohama Bridges.

Identification of Modal Parameters

A dynamic equation of motion under seismic excitation can be written in a discrete-time multivariable linear system, which generally formed by two equations and sequence of Markov parameters equation as follows[1]:

$$w(k+1) = [A]w(k) + [B]u_g(k),$$

$$y(k) = [R]w(k) \text{ and } Y_k = [R][A]^k[B] \quad [1]$$

where [A] is the matrix of structure's mass, stiffness and damping,[B] is matrix of input location and [R] is the transformation matrix to connect the state-system coordinate with the output vector. Provided that the input $u_g(k)$ is a known sequence of ground motion and that the corresponding structure's responses $y(k)$ as outputs, were measured at N locations by sensors, the system matrices of [A],[B] and [R] can be identified using the realization theory[1]. The conventional realization theory such as ERA or ERA D/C [1] relies on the system Markov parameter (Y_k) as inputs for identification. For ambiently excited structure (i.e. unknown input) these Markov parameters can be retrieved using current available technique such as NexT and Random Decrement to obtain impulse response functions. A different modification, however, should be employed for a set of known input-output system. In this paper, an OKID-based approach [2] is utilized to recover the system Markov parameters --a technique, which has been successfully applied in aerospace community. Once the system's Markov parameters have been identified, they can be used in the conventional ERA formulation for the identification of the dynamic structural characteristics. Fig 1.below illustrates the complete procedures for identification.

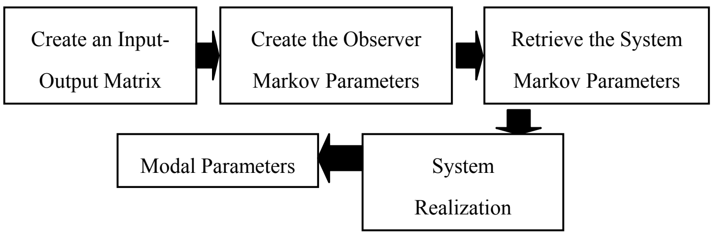

***Figure 1**. Modal Parameters Identification*

Application of the methodology to the Matsunohama Bridges

The proposed methodology is applied to identify structural properties of Matsunohama viaduct. The bridge is supported by laminated rubber bearings (Bridge A) on one end and the by lead rubber bearings (Bridge B) on the other; only the evaluation of Bridge B presented in this paper Both bridges have four continuous spans. One pier of each bridge was instrumented with strong motion accelerometers. The acceleration was measured at four locations: far field, pile cap, pier cap and girder for both bridges in the longitudinal direction. Recorded ground motion consists of main shock and four after shocks, with 60

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seconds of data length each. This data has been previously used by Chaudhary et.al [3] in determining structural properties using 2 DOFs model using a frequency domain system identification. The 2 DOFs are: displacement of the pier and displacement of the girder, which makes this model to be consisting of one DOF each for the super-structure and sub-structure. Abe et al [4] has shown that the super structure of base isolated bridges can be treated as a SDOF system.

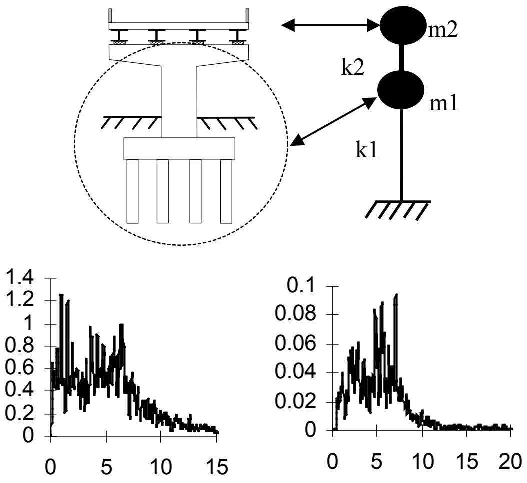

***Fig.2**:a): 2 DOF Idealization of Bridge System*

b) Transfer Function of Pier & Girder

Fourier amplitude spectra of far field and pile cap acceleration are almost the same in the dominant frequency range of 0-10 Hz. Evaluation of Markov sequences suggested that a maximum 4.5 seconds of seismic record length is sufficient to form one frame of Markov sequences. This leaves us with far more data, since the original record was of 60 seconds. However, to minimize the effect of inevitable noise, Markov sequences were computed from 50 different windowed time-histories and then averaged to obtain a sequence of averaged Markov parameters. Fig.3. shows a typical of averaged Markov parameters sequence from an input-output for pier and girder. These responses were then used as input in ERA to estimate structural modal parameters as resulted in Table.1.

Results and Discussion

It can be observed from Fig.3 that the Markov sequences computed from OERA were shown to have the form of decaying response similar to those of typical system's impulse response function. In Table.1, results of the identified natural frequencies and damping ratio indicate that the values are within range dominant peaks showed by transfer function of pier

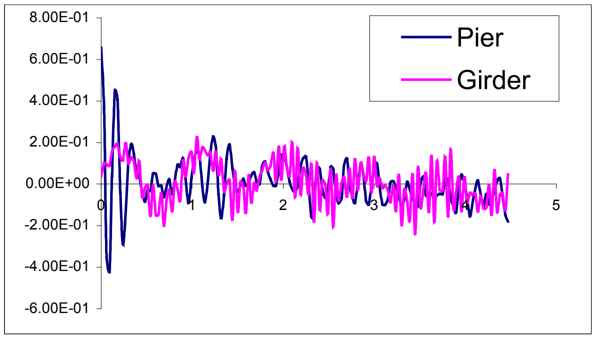

***Fig.3**: Typical Recovered Markov Parameters of Pier & Girder Responses*

	f_1 (Hz.)	f_2 (Hz.)	ξ_1 (%)	ξ_2 (%)
Main Shock	1.07	5.26	9.84	1.36
After Shock 1	1.12	6.72	5.82	0.31
After Shock 2	1.14	6.71	8.44	0.37
After Shock 3	1.65	7.46	5.36	0.37
After Shock 4	1.32	5.17	8.35	0.22

Table 1: Identified Natural Frequencies and Damping from OERA based on acceleration output records

and girder. All measured modes were lightly damped with modal damping ranging from 0.22 to 9.8 %. These modes were considered as real modes, judged from mode-indicators provided by ERA. The advantage of this methodology over standard peak-peaking procedures in the power spectrum is twofold: the ability to identify closely spaced modes and their associated damping and its simplicity, which requires no prior estimation of structural spatial properties.

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