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SEISMIC INTERFEROMETRY FOR DAMAGE IDENTIFICATION OF LARGE SCALE MODEL OF RC SHEAR WALL STRUCTURE

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1. Introduction

The wave method for structural health monitoring (SHM) aims at detecting changes in stiffness of a structure, possibly caused by damage during extreme event, by monitoring changes in the velocity of waves propagating trough the structure [1]. The data used in this study are for a shaking table model of 3 storey reinforced- concrete (RC) shear wall building, which had been tested on the shaking table in the dynamic testing laboratory in IZIIS in Skopje in the frames of SERA project (fig 1). The model was shaken by eleven earthquakes (EQ) with increasing amplitude that progressively damaged it- table 1.

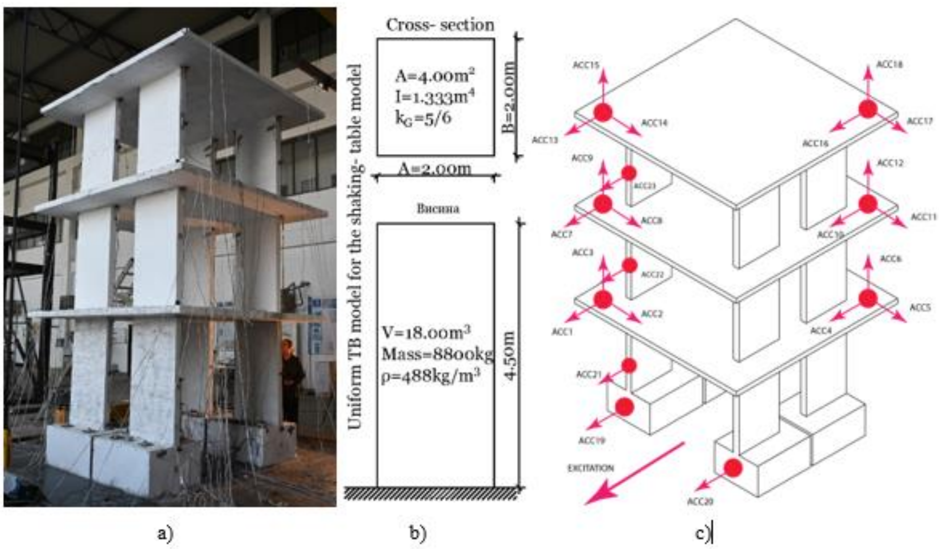

Figure 1. a) Shaking- table model; c) Uniform TB of the model d) Distribution of accelerometers.

2. Methodology

The shaking table model is numerically modelled as uniform Timoshenko beam (TB), of height H=4.5m, stress free at the top, cantilevered at the base (restrained translation and rotation) and excited by base motion- fig 1.b [1]. The material is characterized by mass density, ρ=488kg/m^3, Young's modulus E and shear modulus G, which implies longitudinal and shear wave velocities in the material $c_L=\sqrt{E/\rho}$ and $c_s=\sqrt{G/\rho}$. The beam cross section is with dimensions 2.0mx2.0m, cross- sectional area of A=4.0m^2, second moment of inertia with respect to (w.r.t) axis of excitation of I=1.333m^4 and shear factor of k_G=5/6. The horizontal displacement of the neutral axis of the beam u(z,t) e.g. the solution of the TB under base excitation satisfies the differential equation:

$$c_L^2 c_S^2 k_G \left(1+\mu\frac{\partial}{\partial t}\right)\frac{\partial^4 u}{\partial z^4} - (c_L^2 + k_G c_S^2)\left(1+\mu\frac{\partial}{\partial t}\right)\frac{\partial^4 u}{\partial z^2 \partial t^2} + \frac{k_G c_S^2}{rg^2}\left(1+\mu\frac{\partial}{\partial t}\right)\frac{\partial^2 u}{\partial t^2} + \frac{\partial^4 u}{\partial t^4} = 0 \quad (1)$$

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The equation is solved in the frequency domain and the solution is consequently used to compute the beam transfer- function (2) and impulse response functions (3) as:

$$\hat{h}(z, z_{ref}, \omega) = \frac{\hat{u}(z,\omega)}{\hat{u}(z_{ref},\omega)} = \frac{U(z)}{U(z_{ref})} \qquad (2), \quad h(z, z_{ref}, t) = FT^{-1}\{\hat{h}(z, z_{ref}, \omega)\} \qquad (3)$$

The structure is then identified by matching the model and observed impulse response functions, representing physically the propagation of virtual pulse through the structure (fig 2). The impulse responses and transfer functions were calculated from accelerograms of accelerometers 13 (roof) and 19 (foundations)- fig 1.c. for all tests (fig 2). Two unknown parameters of the TB are c_L and c_S which were calculated by fitting the model and observed impulse responses and transfer functions in specified frequency band 0-11Hz (that included only the first mode) and time band. In this case, the structure is very stiff in shear and deforms predominantly in bending meaning that varying the value of c_S does not introduce error in the fitted functions. Therefore, only the value of c_L was fitted.

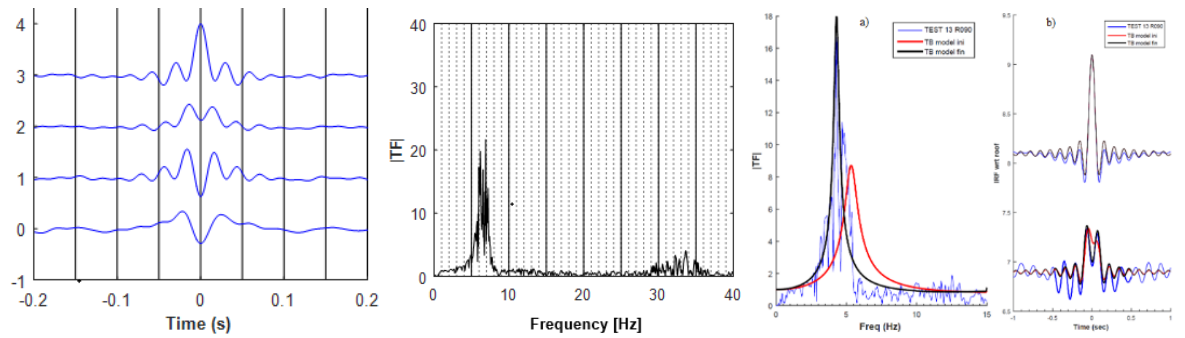

Figure 2. a) IRF for R030; b) TF of roof with respect to foundation for R030 c) Fitting TB for R090

3. Results and discussion

The results from fitting are sublimated in table 1, and one characteristic result is presented in figure 2.c (for R090). Similar results are obtained by fitting for all excitation levels. Table 1 also contains information regarding characteristic observed damage of the model after the tests [2].

Table 1 – Tests, fitted values of c_L and damage description of the model

Test	Fitted value of c_L [m/s]	Change of c_L w.r.t test R010 [%]	Damage description
R010	490	/	
R020	477	2.65	
R030	435	11.22	First crack at contact with foundation- SE pier
R050	390	20.41	
R060(1)	321	34.49	
R060(2)	313	36.12	Crack in all piers- all length of foundation
R080	303	38.16	Horizontal cracks along whole height of all piers in the ground floor
R090	281	42.65	Visible rocking of the model
R120	236	51.84	Cracks in all contacts of piers with slabs- all levels
R150(1)	226	53.88	Concrete crushing in corners of piers
R150(2)	209	57.35	Collapse state

The results from the fitting indicate that it is possible to detect damage in structures using the wave method. C_L as a parameter describing the material of the TB was sensitive to the damage of the test structure, and changes proportional to the level of damage were detected. The reduction of c_L relative to the undamaged state when first cracking in the piers were observed, was about 11%. Reduction of about 38% was detected in the state where horizontal cracks along whole height of all pies in the ground floor were observed. Finally, reduction of more than 50-55% was detected when crushing of concrete and collapse of the structure was observed and stated.

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