17th World Conference on Earthquake Engineering, 17WCEE

Sendai, Japan - September 13th to 18th 2020

ROLE OF DENDITY OF BUILDINGS IN SITE CITY INTERACTION EFFECTS ON SHEAR WAVE RESPONSES OF BUILDINGS AND BASIN

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Abstract

A comparative role of weight/density of building (variation of impedance contrast between building and basin) in the site-city-interaction (SCI) effects on the SH- and SV-wave responses of the buildings and basin under double resonance condition are quantified and presented in this paper. The considered elliptical basin for the SCI study is deep in nature (shape-ratio>0.25). The buildings are incorporated in the numerical grid using building block models and maintaining their dimension, damping, weight and different modes of vibrations. All the buildings of the city are under double resonance condition since a deep basin vibrates with a single fundamental frequency. The obtained level of reduction of fundamental frequency of building and basin, corresponding spectral amplifications as well as splitting of bandwidth of fundamental mode of vibrations of both the basin and buildings corroborates with the findings in the past SCI studies. The buildings are acting as a sub-wavelength resonators and releasing seismic waves back to the basin with a phase difference of 180^0, which in turn causing reduction of response of buildings and basin, particularly in the case later seismic phases due to the destructive interference. The increase of density of building is causing an increase of SCI effects on the response of both the buildings and basin. It is interesting to note that the reduction of fundamental frequency of basin due to the SCI effects is global, even out-side the city. The inferred increase in reduction of fundamental frequencies of both the buildings and basin with an increase of density of buildings of city needs further study considering its earthquake engineering consequences.

Keywords: Site-city-interaction; density of building; double resonance; inertial vibration, coupling.

1. Introduction

The site-city-interaction (SCI) affects the buildings and basin responses due to the combined effects of kinematic soil-structure interaction and inertial structure-soil interaction on a global scale [1, 2, 3, 4, 5, 6]. In most of the past SCI studies, the cities were considered on a 1D-basin or in a 2D-shallow basin (shape-ratio<0.25) under double-resonance condition and results were in the form of reduction of fundamental frequencies of building and basin, corresponding spectral amplification factors (SAF), and splitting of the bandwidth of fundamental mode of vibrations of buildings and basin [7, 8, 9, 10, 11]. Shape-ratio of the basin is simply the ratio of maximum depth of basin to its half effective width. Double resonance is the matching of frequency of the incoming signal with the fundamental frequency of basin (F_{02D}^{B}) and further matching with the fundamental frequency of building on rock (F_{02D}^{S}). Some researchers have also studied SCI theoretically and have validated the outcomes with numerical and experimental results [12]. The response of 2D-deep basin (shape-ratio>0.25) is dominated with a 2D resonance phenomenon and entire basin vibrates with a single resonance frequency [11, 13]. In contrast to this, the response of 2D-shallow basin is dominated with the basin generated surface waves [14]. The real buildings are incorporated in the numerical grid using building block model (BBM) and maintaining their dimension, damping, weight and different modes of vibrations [4, 10]. The dynamic parameters like values of moduli, damping and density of the building may vary with the design, type of building, social status of a city/society and the approach followed to finalize the building parameters [6, 8, 15, 16]. Now, two questions arise whether the reduction of F_{02D}^{B} of deep-basin due to SCI effects will be global or local as well as what will be the role of density of building in the SCI effects on the responses of buildings and basin.

In order to find-out the answers to the above raised questions, the SH- and SV-wave responses of the buildings of a city situated in a 2D-deep elliptical basin and free field motion were simulated under double-resonance condition for different density of the BBM and analysed. The dimension and rheological parameters of sediment of the elliptical basin and rock are same in all the considered site-city models for a particular polarization of the S-wave. To quantify the SCI effects on the response of building, the response of a standalone building at the centre of elliptical basin was considered as a reference one. Similarly, the SCI effects on the response of basin were quantified considering the response of basin in the absence of city as a reference one. The SH- and SV-wave responses of the various considered site-city models were simulated using fourth-order accurate viscoelastic staggered-grid SH- and SV-wave finite-difference programs written by Narayan and Kumar [17, 18].

2. Model parameters

To study the SCI effects on the SH- and SV-wave responses of buildings and basin under double resonance condition, 16-story (B16) and 12-story (B12) buildings of width 60 m were considered for SH- and SV-wave site-city models, respectively based on the prevailing Indian scenario of construction of buildings [16]. The buildings were incorporated in the numerical grid using a homogenous building block model (BBM), but, making sure that the different modes of vibrations, dimension, damping and weight of the BBM are same as that of the real building, as shown in Fig.1 [4, 15]. Recently, Michel and Gueguen [19] reported a range for effective S-wave velocity in the buildings as 100-500 m/s depending on the type, dimension and the design. The density of the building can vary depending on the type, dimension and design, which can be obtained using the weights of all the walls, beams, columns, slabs of building and the live load [15]. In order to study the role of density or impedance contrast (IC) between the building and basin in the SCI effects on the SH- and SV-wave responses, four WBH1-WBH4 site-city models for the SH-wave and four WBV1-WBV4 site-city models for the SV-wave simulations were taken. The density of building was increased keeping in mind that the S-wave velocity for the BBM is unchanged. The S-wave velocity and density for the BBM for different considered models is given in Table 1.

In this paper, the building's fundamental frequency on rock is defined as transverse (F_{02D}^{TR}) and flexural(F_{02D}^{FR}) for the SH- and SV-polarizations, respectively. The F_{02D}^{TR} frequency of B16-BBM on rock, in the case of SH-wave excitation, can be obtained as 0.62 Hz using relation $F_{02D}^{TR} = \frac{V_S}{4H}$ since it will behave as a shear beam [19]. In contrast to this, BBM may behave like a bending beam when excited with the SV-wave and F_{02D}^{FR} of the BBM may be lesser [11, 19]. The damping and Poisson's ratio for the BBM were taken as 5% and 0.25, respectively. The rheological parameters like S-wave velocity, density and Poisson's ratio for basin were taken as 300 m/s, 1800 kg/m^3 and 0.4, respectively. Similarly, the S-wave velocity, density and Poisson's ratio for rock were taken as 1800 m/s, 2500 kg/m^3 and 0.25, respectively.

3. Response of standalone building on rock and in basin

In order to have a double resonance the fundamental frequency of BBM on rock and basin should match. Kumar and Narayan [11] reported that F_{02D}^{B} of basin varies with the polarization of the S-wave. The fundamental frequency of standalone BBM on rock as well as basin were numerically computed in this sub-section to make sure that basin and BBM are under double resonance condition for a particular polarization of the S-wave.

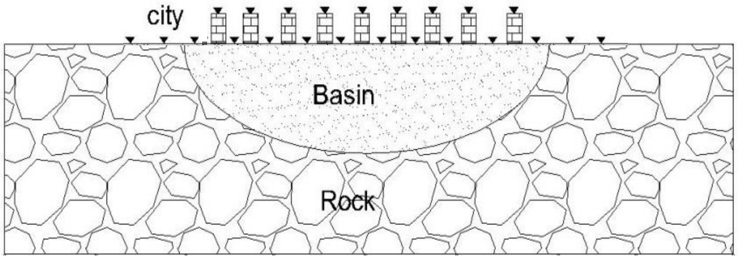

Fig.1 – Vertically exaggerated sketch for the various site-city models (Note: the number of buildings are nine and five and width of basin is 492 m and 660 m for the SH- and SV wave simulations, respectively).

Table 1 – The S-wave velocity and density of BBM for the WBH1-WBH4 and WBV1-WBV4 site-city models (Note: rheological parameters for basin and rock are same in all the models).

Site-city models	V_S **(m/s)**	**Density (g/cc)**
WBH1/WBV1	120	250
WBH2/WBV2	120	350
WBH3/WBV3	120	450
WBH4/WBV4	120	550

3.1 The SH- and SV-wave response of standalone BBM on rock

To find out the fundamental frequency of BBM for the SV-wave on rock (F_{02D}^{FR}), the P-SV wave responses of the considered standalone B4 (height 12 m), B8 (height 24 m) and B12 (height 36 m) building on rock were computed using a vertically propagating plane wave front of SV-wave [18]. The width of buildings was taken as 60 m. The left panel of Fig.2 depicts the horizontal component of motion at the top of B4, B8 and B12-buildings. An increase of duration and decrease of amplitude of motion of building can be inferred with an increase of height. The right panel of Fig.2 reveals the spectral amplification factors (SAF) for the horizontal motion at the top of B4, B8 and B12-buildings. The SAFs were computed using simply the ratio of spectra of the horizontal component of motion at the top of building and that on the exposed rock. Analysis of Fig.2 revealed a decrease of value of $F_{02D}^{FR}$of the BBM with an increase of height of building for a fixed width [11, 20]. Further, the numerically obtained F_{02D}^{FR} of the B12, B8 and B4-buildings as 0.66 Hz, 1.06 Hz and 2.34 Hz, respectively for SV-wave are lesser than those for SH-wave obtained using relation $F_{02D}^{TR} = \frac{V_S}{4H}$ as 0.83 Hz, 1.25 Hz and 2.50 Hz.

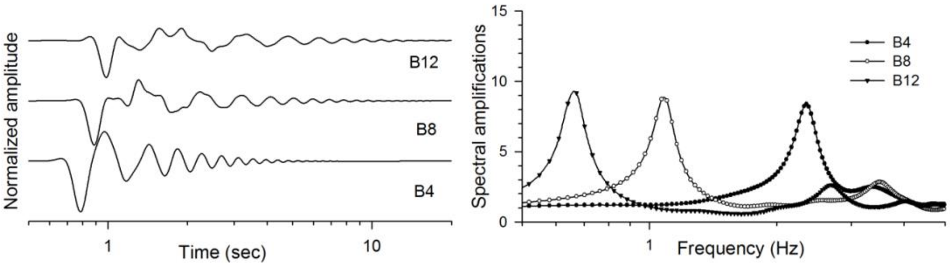

Fig. 2 – The horizontal component of the P-SV wave responses (left) and spectral amplifications (right) at the top of B4, B8 and B12-buildings.

The SH-wave responses of the standalone B16-BBM on the rock with the rheological parameters corresponding to WBH1-WBH4 site-city models were computed using a vertically propagating plane wave front of the SH-wave [17]. The computed SAFs at the top of B16-BBM for different density of BBM are shown in the left panel of Fig.3a. The obtained $F_{02D}^{TR}$of B16 building around 0.62 and corresponding SAFs around 11.3 in the WBH1-WBH4 models, respectively revealed that F_{02D}^{TR} and corresponding SAF is almost unaffected by the change of density of BBM. Similarly, the computed SAFs of horizontal component of motion at the top of B12-BBM for different density of BBM in the WBV1-WBV4 models are shown in the right panel of Fig.3a. The obtained $F_{02D}^{FR}$of the B12 building as 0.663 Hz, 0.666 Hz, 0.672 Hz and 0.674 Hz and corresponding SAFs as 9.4, 9.2, 8.98 and 8.76 in the WBV1-WBV4 models, respectively revealed minor decrease of F_{02D}^{FR} and SAFs with increase of density of building [12, 19].

3.2 The SH- and SV-wave responses of elliptical basin

The obtained F_{02D}^{TR} of B16-BBM as 0.62 Hz and F_{02D}^{FR} of B12-BBM as 0.66-0.67 Hz depicts that the fundamental frequency of elliptical basin for the SH-wave (SHF_{02D}^{B}) and SV-wave (SVF_{02D}^{B}) should also be of the order of 0.62 Hz and 0.66 Hz, respectively to maintain the double resonance condition. Kumar and Narayan [11] have given an empirical relation to predict the $SHF_{02D}^{B}$of 2D deep basin (shape-ratio>0.25) in terms of lowest 1D fundamental frequency ($F_{01D}^{B} = \frac{V_S}{4h}$) and maximum depth 'h' and effective half-width 'w' (effective width is the span over which the depth (h) is ≥h/2).

$$SHF_{02D}^{B} = F_{01D}^{B}\left(\sqrt{1+1.6(h/w)^2}\right) \tag{1}$$

The estimated maximum depth, effective width (2w) and actual width of elliptical basin for $SHF_{02D}^{B} = 0.62\ Hz$ are 150 m, 378 m and 492 m, respectively using Eq. 1. The left panel of Fig.3b show the SAFs at a distance of 39 m from the centre of elliptical basin. The obtained $SHF_{02D}^{B}$of elliptical basin as 0.627 Hz reveals that B16-buildings of city and basin are in co-resonance for the SH-wave simulations. Bard and Bouchon [13] have given an empirical relation to predict the $SVF_{02D}^{B}$of 2D deep basin (shape-ratio>0.25).

$$SVF_{02D}^{B} = F_{01D}^{B}\sqrt{[1+(2.9h/2w)^2]} \tag{2}$$

The inferred depth, width and effective width of the elliptical basin for $SVF_{02D}^{B} = 0.66\ Hz$ are 150 m, 660 m and 505 m, respectively using Eq. 2. The right panel of Fig.3b show the computed SAFs at a distance of 36 m from the centre of elliptical basin. Now, the numerically obtained $SVF_{02D}^{B}$of elliptical basin as 0.662 Hz reveals that B12-buildins of city and basin are in co-resonance for the SV-wave simulations.

4. Role of density/IC in SCI effects on SH-wave responses

In order to infer the role of density/IC between the building and the basin in the SCI effects, the SH-wave responses of buildings corresponding to four WBH1-WBH4 site-city models were simulated (Table 1). In all the site-city models five-B16 buildings are considered in the elliptical basin (Fig.1). The buildings of width 60 m are situated at an equal spacing of 15 m in the basin. The centre of 3rd building is at the centre of basin.

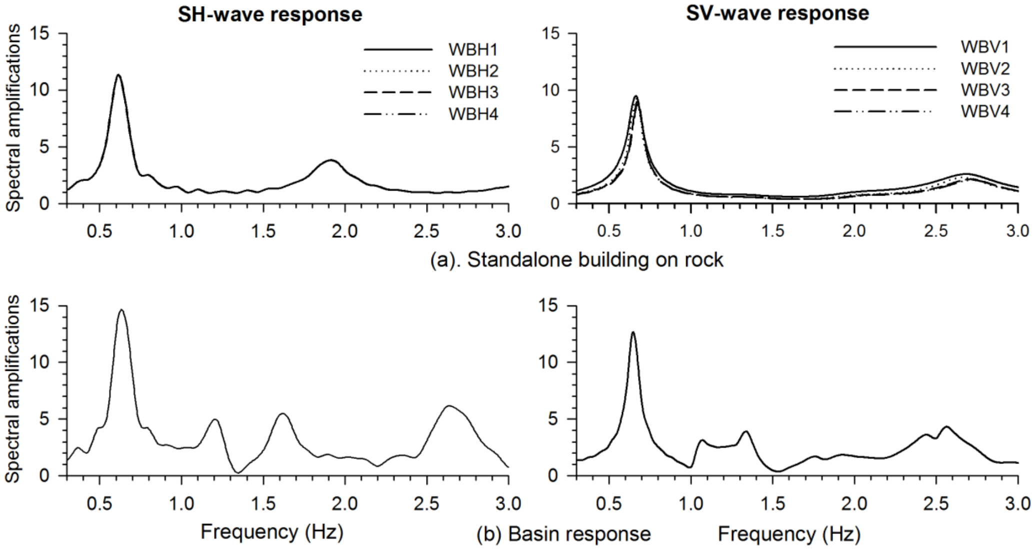

Fig. 3a&b – The SAFs at the top of standalone BBM on rock with impedances corresponding to the WBH and WBV city-models and SAFs at a distance of 36 m from the centre of elliptical basin in the case of SH- (left panel) and SV-wave (right panel) responses.

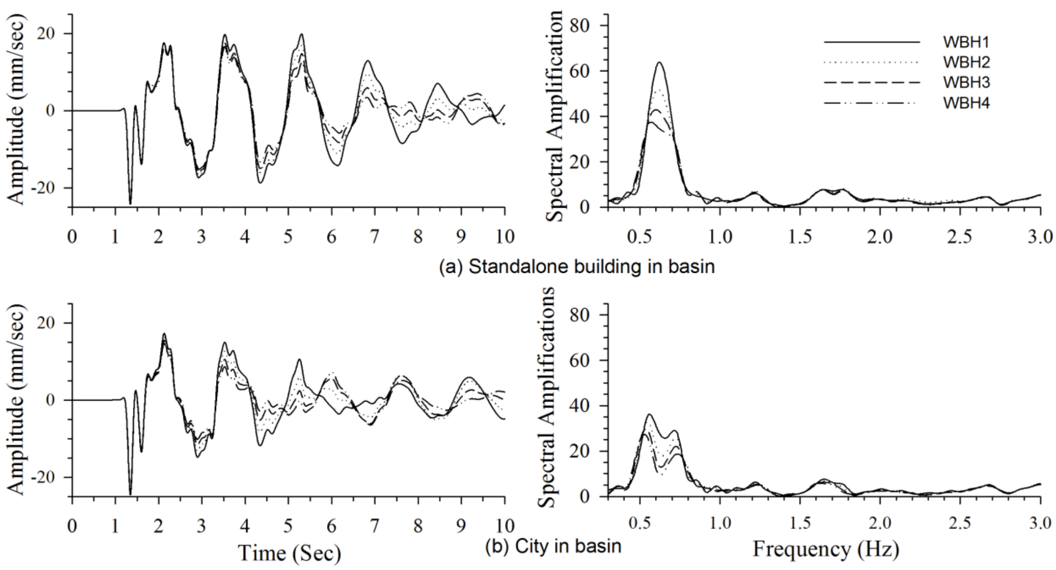

Fig. 4a&b – The SH-wave responses (left panels) and spectral amplifications (right panels) at the top of standalone building situated at the centre of elliptical basin and at the top of the building situated at the centre of city, respectively.

4.1 Standalone building at centre of elliptical basin

The left and right panels of Fig.4a depict the SH-wave responses at the top of standalone building situated at centre of elliptical basin and corresponding SAFs in the WBH1-WBH4 site-city models, respectively. A considerable decrease of amplitude of response at top building with increase of density/impedance of BBM can be inferred, particularly in the case of later recording. The obtained transverse fundamental frequency of building situated in basin (F_{02D}^{TB}) as 0.62 Hz, 0.61 Hz, 0.60 Hz and 0.57 Hz in the WBH1-WBH4 models, respectively reveals the decrease of F_{02D}^{TB} with increase of density/impedance of building. The obtained SAF at F_{02D}^{TB} of building as 63.18, 51.89, 42.68 and 35.24 were 5.6, 4.6, 3.8 and 3.1 times larger than that at F_{02D}^{TR} of standalone building on rock in the WBH1-WBH4 site-city models, respectively. The obtained very large amplification at the top of standalone building in basin as compared to the standalone building on the rock revealed the effect of occurrence of double resonance phenomenon. The obtained decrease of F_{02D}^{TB} of building with increase of impedance of BBM reflects the increase of soil-structure-interaction (SSI) effect on the building response.

4.2 City situated in the elliptical basin

4.2.1 SCI effects on the response of buildings

The SH-wave responses and corresponding SAFs at the top of 3rd building of the WBH1-WBH4 site-city models is shown in the left and right panels of Fig.4b. It is very much clear that the SCI has caused large reduction of response at top of building, particularly in the case of later phases, as compared to the SSI. The obtained 9.5% further reduction of $F_{02D}^{TB}$of the 3rd building in all the models revealed that SCI effect in reduction of $F_{02D}^{TB}$of the building is more than that due to SSI. The obtained SAFs at F_{02D}^{TB} of 3rd building as 36.06, 33.23, 29.98 and 25.92 in the case of WBH1-WBH4 site-city models, respectively revealed a decrease of SAFs with an increase of density of building. Table 2 reveals that SCI effects due to only 5-buildings have caused % reduction of SAF at F_{02D}^{TB} of the order of 42.92%, 35.96%, 30.71% and 26.95% in the WBH1-WBH4 site-city models, respectively as compared to SSI effects.

Table 2 – A comparisons of SAFs in the case of standalone building in basin and building at the centre of city (3rd building of the city) and corresponding % reduction of SAFs due to the SCI effects at F_{02D}^{TB} and F_{02D}^{TR} in the WBH1-WBH4 models and at F_{02D}^{FB} and F_{02D}^{FR} in the WBV1-WBV4 models.

Site-city models	**SAF at F_{02D}^{TB} / F_{02D}^{FB} of building**			**SAF at F_{02D}^{TR} / F_{02D}^{FR} of building**		
	Standalone	**City**	**% reduction**	**Standalone**	**City**	**% reduction**
WBH1	63.18	36.06	42.92	63.11	29.90	52.67
WBH2	51.89	33.23	35.96	51.78	20.56	60.37
WBH3	42.68	29.58	30.71	42.57	14.61	65.79
WBH4	35.24	25.92	26.95	35.12	10.66	69.75
WBV1	82.82	38.77	53.18	79.11	26.92	65.97
WBV2	67.27	34.41	48.84	61.36	20.02	67.o7
WBV3	55.19	30.70	44.37	51.48	13.29	74.18
WBV4	46.77	29.08	37.82	42.94	9.51	77.85

Table 3 – A comparisons of SAFs at F_{02D}^{B} and F_{02D}^{TR} / F_{02D}^{FR} at a distance of 39 m and corresponding % reduction of SAFs due to the SCI effects at frequencies F_{02D}^{B} and F_{02D}^{TR} in the WBH1-WBH4 models and at frequencies F_{02D}^{B} and F_{02D}^{FR} in the WBV1-WBV4 models.

Site- city models	**SAF at F_{02D}^{B} of basin**			**SAF at F_{02D}^{TR} / F_{02D}^{FR} in free field motion**		
	Without city	**With city**	**%reduction**	**Without city**	**With city**	**% reduction**
WBH1	13.74	7.72	43.81	12.64	2.94	76.74
WBH2	13.74	7.31	46.74	12.64	2.32	81.64
WBH3	13.74	7.02	48.90	12.64	1.25	90.11
WBH4	13.74	6.86	50.10	12.64	0.53	95.80
WBV1	12.54	8.14	35.08	10.61	2.59	75.58
WBV2	12.54	7.62	39.23	10.61	2.14	79.83
WBV3	12.54	7.34	41.46	10.61	1.33	87.46
WBV4	12.54	7.08	43.54	10.61	0.92	91.32

However, the obtained % reduction of SAF at frequency F_{02D}^{TR} as 52.67%, 60.37%, 65.79% and 69.75 in the WBH1-WBH4 site-city models, respectively may be due to an increase of amplitude of seismic wave caused by the inertial vibrations of a particular building, which is out of phase to that of the incident SH-wave, which in turn has caused drastic reduction of response of other buildings, particularly in the case of later phases (Pl. see Fig.4b).

4.2.2 SCI effects on free field motion

To quantify the role of IC between the building and basin in the SCI effects on the response of basin, the SH-wave responses were computed at a distance of 39 m, 114 m and 189 m. The third receiver point was 9 m away from the edge of the city. The left panel of Fig.5a-d depicts the comparison of spectral amplifications computed for with (continuous line) and without (dotted line) city at different locations in the basin for the WBH1-WBH4 site-city models, respectively. Analysis of Fig.5 revealed a decrease of SAF due to SCI effects and it is further decreasing with increase of density of building (decrease of IC). It is interesting to note that there is decrease of SHF_{02D}^{B} of basin due to the SCI effects and this decrease is further increasing with increase of density of building. For example, the obtained reduction of SHF_{02D}^{B} of basin due to SCI effects was 13.6% and 20.0% in the WBH1 and WBH4 site-city models. Table 3 shows an increase of % age reduction of SAF at $SHF_{02D}^{B}$of basin as compared to that in the absence of city with increase of density of building. The obtained larger reduction of SAF at frequency F_{02D}^{TR} and its increase with increase of density of building may be due an increase of amplitude of seismic wave emanated during the inertial vibrations of the buildings. Further, the larger reduction of SAF at F_{02D}^{TR} *as compared to* SHF_{02D}^{B} may be responsible for the splitting of the bandwidth of the fundamental mode of vibration of basin as was inferred in the case of building's response (Table 3).

5. **Role of density/IC in SCI effects on SV-wave responses**

To quantify the role of density/IC in the SCI effects on the SV-wave responses of buildings and the basin, four WBV1-WBV4 site-city models were considered (Table 1). Fig.1 illustrates the sketch for the vertically exaggerated site-city model with nine B12-buildings situated in the elliptical basin. The maximum depth and width of the elliptical basin were taken as 150 m and 660 m, respectively.

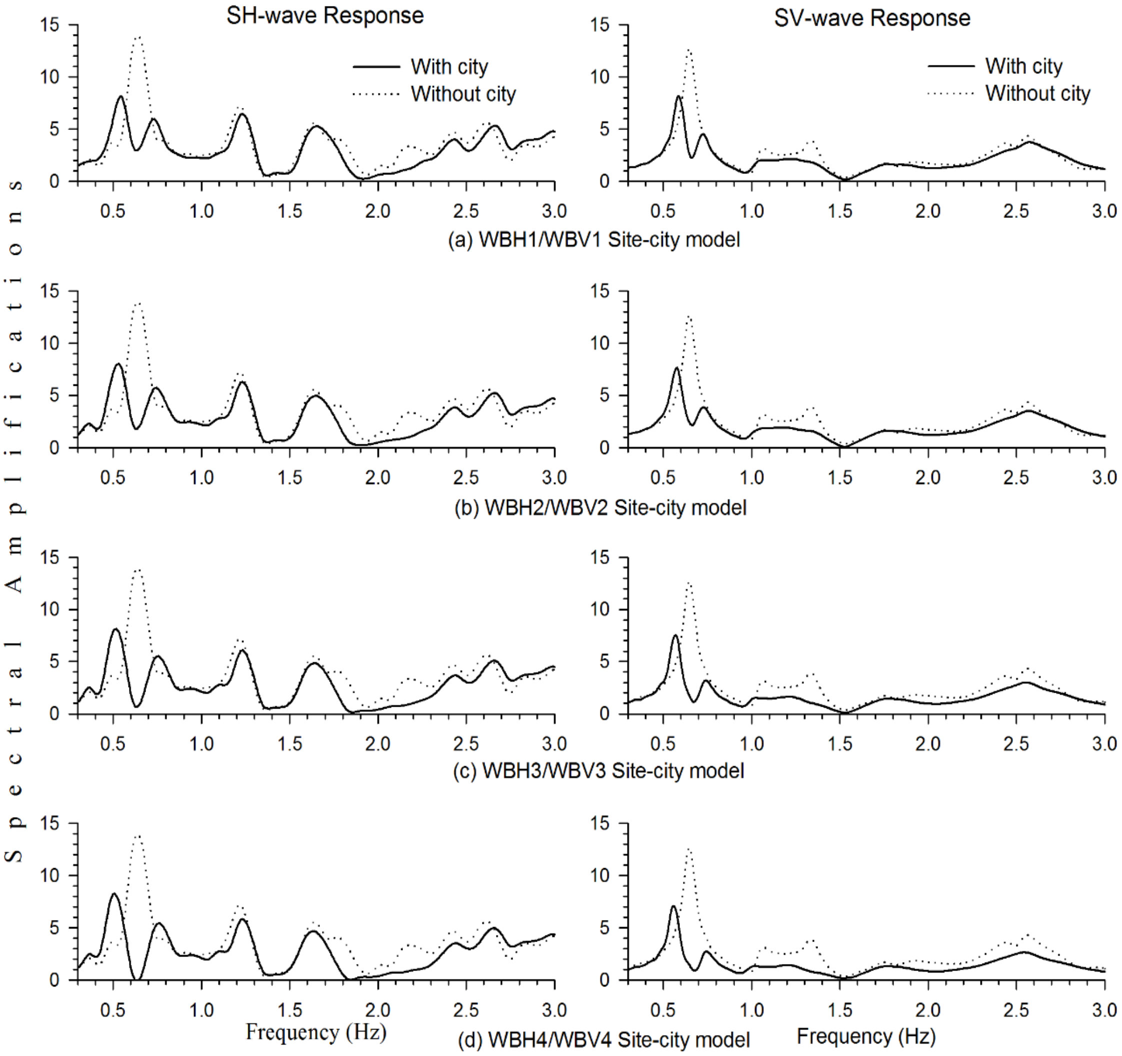

Fig. 5a-d – A comparison of spectral amplifications at distance of 39 m and 36 m in the elliptical basin corresponding to with and without city in basin in the WBH1-WBH4 (left panels) and WBV1-WBV4 (right panels) site-city models, respectively.

The width of B12 buildings was taken as 60 m and spacing between two consecutive buildings was 12 m. The buildings of the city were numbered as 1st, 2nd, …. and 9th building from left to right edge of the city. Further, the centre of 5th building was at the centre of elliptical basin. The free field motions were computed on a horizontal array with 14-equidistant (72 m apart) receiver points, extending from 486 m left to 468 m right of the centre of elliptical basin.

5.1 Solo-building at the centre of basin

Fig.6a shows a comparison of horizontal component of the SV-wave responses at the top of standalone B12-building situated at the centre of basin (left panel) and corresponding SAFs (right panel) in the WBV1-WBV4 models. The double resonance phenomenon was responsible for many fold increase in spectral amplifications. For example, the obtained SAFs at F_{02D}^{FB} as 82.22, 67.27, 55.19 and 46.77 in the WBV1-WBV4 models, respectively were 8.81, 7.31, 6.14 and 5.33 times larger than those obtained at F_{02D}^{FR} of building, respectively (Table 2). The decrease of SAF at F_{02D}^{FB} is due an increase of impedance of the BBM. A decrease of F_{02D}^{FB} of building due to SSI as compared to F_{02D}^{FR} can be inferred, but, there is no further considerable decrease of F_{02D}^{FB} due to an increase of density of building. For example, the F_{02D}^{FB} was around 0.64 Hz in the WBV1-WBV4 models. There was no splitting of the spectral bandwidth of F_{02D}^{FB} of building.

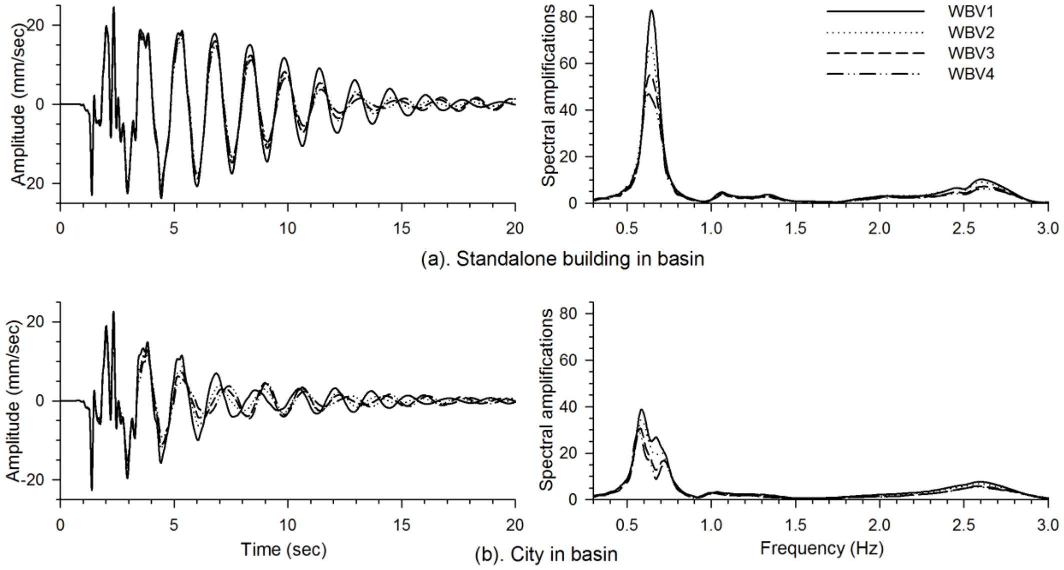

Fig. 6a&b – A comparison of the SV-wave responses (left) and spectral amplifications (right) at the top of a standalone building at the centre of basin and at the top of 5th building situated at the centre of WBV1-WBV4 site-city models, respectively.

5.2 SCI effects on building and basin responses

The left panel of Fig.6b shows the horizontal component of P-SV wave responses at the top of 5th building of the WBV1-WBV4 site-city models. This figure revealed a decrease of amplitude and SAFs at the top of building with an increase of impedance of building. The SCI effects has further reduced the F_{02D}^{FB} of building as 0.58 Hz in the WBV1-WBV4 models. The obtained SAF at $F_{02D}^{FB}$of 5th building as 38.77, 34.41, 30.70 and 29.08 in the WBV1-WBV4 site-city models, respectively were 53.18%, 48.84%, 44.37% and 37.42% lesser than those obtained in the respective case of the standalone building at the centre of elliptical basin (Table 2). On the other hand, the obtained % increase of SAF at F_{02D}^{FR} as 65.97%, 67.07%, 74.18% and 77.85% in the WBV1-WBV4 site-city models, respectively may be due to an increase of inertial vibration of building with increase of density.

The computed free field SV-wave responses of the WBV1-WBV4 site-city models for without and with city in basin revealed a considerable decrease of amplitude due to the SCI effects (result not shown here). The right panel of Fig.5 (a-d) depicts the comparison of SAFs of the horizontal component of the SV-wave for without and with city in the basin at a distance of 36 m for the WBV1-WBV4 models, respectively. An increase of reduction of SVF_{02D}^{B} of basin with increase of density of building can be inferred. For example, this reduction was 10.0% and 14.5% in the entire basin in the WBV1 and WBV4 models. SCI has caused reduction of SAF in the free field motion at all the frequencies and this reduction at $SVF_{02D}^{B}$of basin was of the order of 35.08%, 39.23%, 41.4% and 43.54% in the WBV1-WBV4 site-city models, respectively at a distance of 36 m. In contrast to this, the reduction of SAF F_{02D}^{FR} due to SCI was of the order of 75.58%, 79.83%, 87.4% and 91.32% in WBV1-WBV4 site-city models, respectively. The obtained larger % reduction of SAF at F_{02D}^{FR} of building on rock as compared to at SVF_{02D}^{B} of basin may be due to the destructive interference of incident SV-wave with the seismic wave caused by inertial vibration of building at frequency F_{02D}^{FR} and this difference is increasing with increase of density of buildings.

6. Conclusions

The obtained reduction of fundamental transverse and flexural frequencies of building, fundamental frequency of basin, corresponding SAFs as well as splitting of bandwidth of fundamental mode of vibrations of both the basin and buildings corroborates with the findings in the past SCI studies [7, 8, 9, 11, 20]. The buildings are acting as a sub-wavelength resonators and the released seismic waves by the building back to basin are causing reduction of response of buildings and basin due to destructive interference, since the emanated seismic waves are out of phase to that of incident S-wave [21]. The increase of density of building for a fixed value of S-wave velocity is causing the increase of impedance of building and decrease of impedance contrast (increase of coupling) between the building and basin. The increase of coupling has caused an increase of amplitude of seismic waves imparted back to the basin at frequencies $\mathrm{F}_{02\mathrm{D}}^{\mathrm{TR}}$ and F_{02D}^{FR} , which in turn is causing an increase of SCI effects on the response of both the buildings and basin [12]. But, the rate of increase of SCI effects on the reduction of SAF at only $\mathrm{F}_{02\mathrm{D}}^{\mathrm{FB}}$ *and* $\mathrm{F}_{02\mathrm{D}}^{\mathrm{TB}}$ frequencies with increase of density is lesser than that in the SSI but reverse was the case at $\mathrm{F}_{02\mathrm{D}}^{\mathrm{FR}}$ *and* $\mathrm{F}_{02\mathrm{D}}^{\mathrm{TR}}$ frequencies of building. The inferred lesser SCI effects in the SV-wave simulations as per expectation may be due to the recording of emanation seismic waves in both the horizontal and vertical components. It was interesting to note that the reduction of $\mathrm{F}_{02\mathrm{D}}^{\mathrm{B}}$ of basin due to the SCI effects was global, even out-side the city.

7. Acknowledgement

The first author is thankful to Indian Institute of Technology, Roorkee for providing financial support for presenting this paper in 17WCEE, Japan.

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