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THE SPREAD PHENOMENON OF A LOW FREQUENCY GROUND VIBRATION TO ORIGINATE IN THE HIGHWAY BRIDGE AND ITS SIMULATION ANALYSIS

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ABSTRACT

As for M highway bridge, it had the one for temporary be opened to traffic by July 2004. Because of that, vibration investigation was carried out to investigate this vibration cause. The complaint to face vibration from the nearby private house was sent along with this. While three houses of private houses stand in a line, as for the point which it should pay attention to in the complaint of the former term, central B house shakes sideways, and a left right private house is the point not to be shaking. When it thinks about this point, a certain vibration spreads, and reaches it from the M highway bridge to three houses through the ground. A main vibration influence to give to private house is the running vibration of a big car to run through the M highway bridge. A vibration to spread to the private house in the neighborhood is the vibration of the beam, and that characteristic frequency of vibrations is about 3.0Hz in the phenomenon.

INTRODUCTION

As for the M highway bridge, it had the one for temporary be opened by July, 2004 (the side for west). Because of that, vibration investigation was carried out to investigate this vibration cause. The complaint to face a vibration from the nearby private houses was sent along with this. While three houses of private houses stand in a line, a for the point which it should pay attention to in the complaint of the former term, central the B house (three storied high) shakes sideways, and a left-right private houses (two storied high) is the point not to be shaking. When it thinks about this point, a certain vibration spreads, and reaches it from the M highway bridge to three houses through the ground. It guesses that amplitude of the house amplifies by the resonance phenomenon, because it is close to that frequency of vibrations that the characteristic frequency of vibrations of the house of central the B house spreads. Photograph 1 shows the M highway and the three private houses are discussed in this paper.

Generally, it thinks of the characteristic frequency of vibrations of the private house with about 3.0-7.0 Hz, and beam bends the phenomenon it can think to cause this nearby vibration in the vibration (the characteristic frequency of vibration on the bridge side) which a bridge occurs in 3.0-7.0Hz, and vibrates, and it can think about the twist vibration of beam, the rotation vibration of pier, and so on. And because it was located in the P34 pier (joint part) near here, as for the M building, the shock vibration when vehicles passed through the joint as a vibration was measured, too.

The velocity type seismometer whose measurement precision to the low frequency of vibration element was good was used the above thoroughway to select a position of the measurement in the cause and to make the comparatively low frequency of vibration of a target. But, an accelerometer was used for the measurement in upper part that a velocity type seismometer can't be installed, and a vibration level meter was used for the measurement of the officials and people boundary.



Photograph 1. M highway

MEASUREMENT OUTLINE

The measurement points are shown in Figure 1. A sensor was installed in a position of each measurement of the M highway bridge, and connected to two measurement systems with extension cable through the amplifier. Next, the portable type seismometer was installed in the B house and a vibration level

meter was installed in the officials and people boundary. Then, timing was measured with transceiver and so on after the meter adjustment, and a record was started at the same time, and five minutes and an oscillatory wave form nine minutes were recorded with each measurement pattern twice.

CONSIDERATIONS

A vibration influence to give the private house

As for the record of the B house of the Figure 2, the big phenomenon which appears in the M highway bridge of 1 channel to 6 channels is when a heavy vehicles passes through the M highway bridge when a form is seen. Next, as for the main vibration which occurs in the private house side, the neighborhood can be confirmed in the neighborhood near here for 70 seconds and for 110 seconds and for 16 seconds. This vibration appears at the timing which is the same as when large vehicles pass through the M highway bridge. A big phenomenon appears in the ground around the pier as well at the same timing. The vibration when all the large vehicles run through the M highway bridge spreads in the ground around the pier, and it is understood that it reaches it to the private house from these phenomena.

Figure 3 is the typical case when a large car runs through the M highway bridge. This figure arranged the wave form of upper part for the west side from the P34 pier. The shocking vibration phenomenon (A in the figure and B) which appears in 1 channel of these record wave forms and 8 channels is the phenomenon when vehicles pass through the joint on the pier. Furthermore, the phenomenon (a in the figure, b, c and d) that the high frequency of vibration mixes with the low frequency of vibrations to appear in two channels, three channels, four channels and six channels is the phenomenon when vehicles

pass through the center of the span. After vehicles passed on the P34 pier with A in the figure and it passed on each beam span center in turn, it can confirm that it reaches a P38 pier with B in (a in the figure, b, c and d), the inside of the figure. When a Z direction in the center of this beam span is seen, aside from the high frequency of vibrations, the vibration phenomenon of 2.0-4.0Hz is seen. That size is thought an influence in the Z direction because a Z direction is big from several times the Y direction by several times though it is seen in the Y direction as well. Therefore, it can think about this vibration with the vibration in the up-down direction (Z direction) of the beam.

The vibration cause of the private house

The vibration phenomenon which occurs when a structure vibration is divided roughly in the resonance phenomenon cause that it amplifies because and the frequency of the input vibrations is close to the characteristic frequency of vibrations which a structure has when the frequency of vibrations which moving a structure appears directly may. So, two houses of vibration causes are confirmed.

About the B house. It is understood that the vibration which occurs in the ground around the private house (B house) more than above is the neighborhood 3.0Hz. The beam of M highway bridge bends it, and the ground can be thought this to spread the vibration. This characteristic frequency of vibrations of 3.0Hz and the beam where it spread from the characteristic frequency of vibrations in the X direction of the B house being 3.0 Hz and 4.3Hz bend it, and resonance phenomenon with the vibration (3.0Hz) occurs, and it can think that it is the horizontal vibration which big peak like an upper step (a spectrum figure in the 3rd floor X direction) of the Figure 4 is shown in.

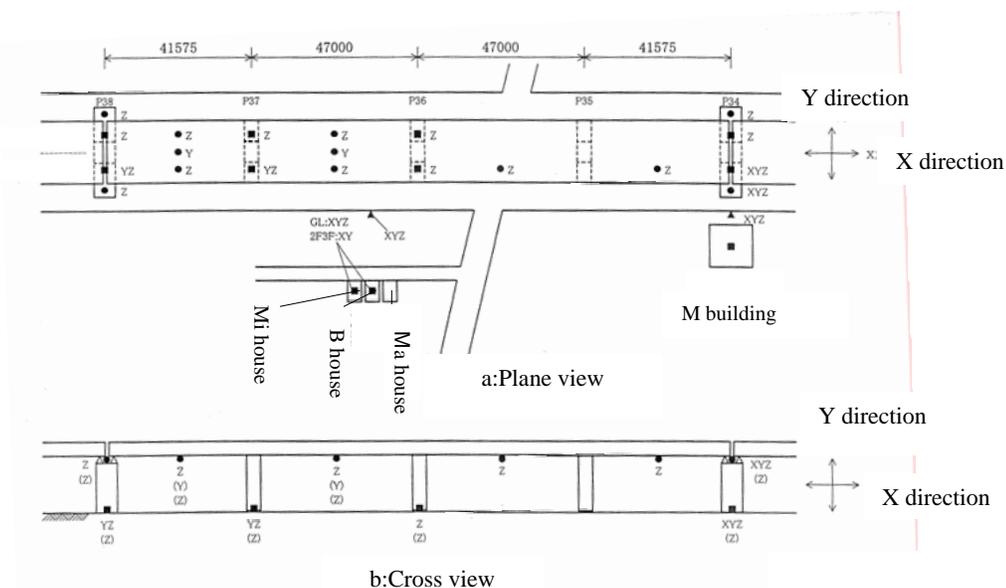


Figure 1. Measurement points on the highway bridge

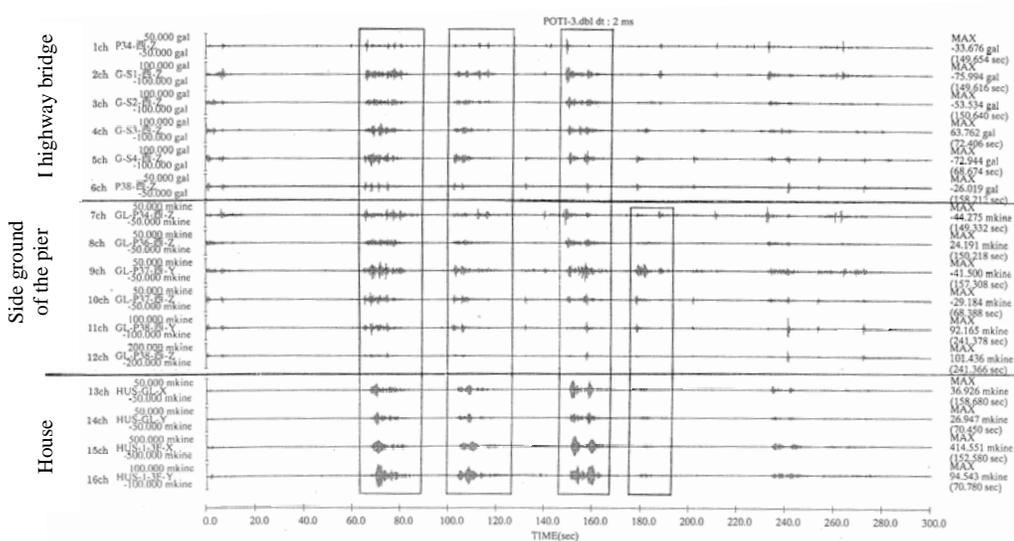


Figure 2. Measurement wave forms of acceleration (1 to 6 ch) and ones of velocity (7 to 16ch) on the B house

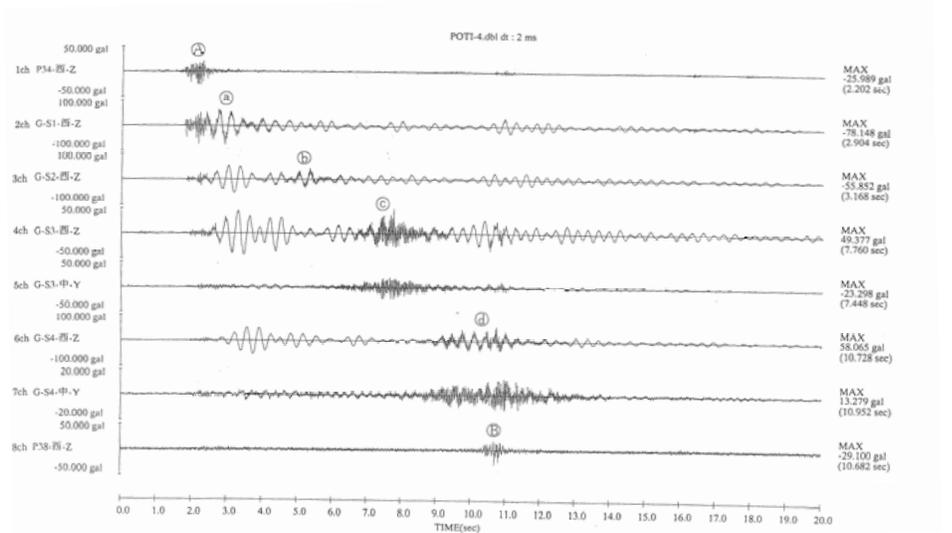


Figure 3. Representative wave forms on the running of big truck

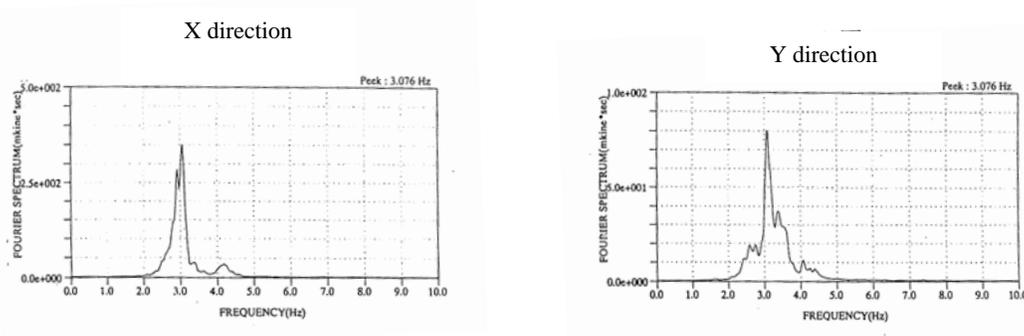


Figure 4. Fourier spectrum on the B house

The vibration of 10 times and more of the vibration of the ground around the private house occurs in the house by resonance. (13 channels of the Figure 2, 15 channels reference) The beam of M highway bridge bends it, and the beam where it spread but it spread bends the ground, and a vibration doesn't occur in the M house as well which adjoins it from the

characteristic frequency of vibrations (4.4Hz) of the M house coming off the mountain as for resonance phenomenon when the inclination of the mountain of the spectrum figure of the vibration (the ground around the private house) is seen. Therefore, though it amplifies on the 2nd floor a little, the M house vibration only 1.7 times. 13 channels of the Figure 3, and

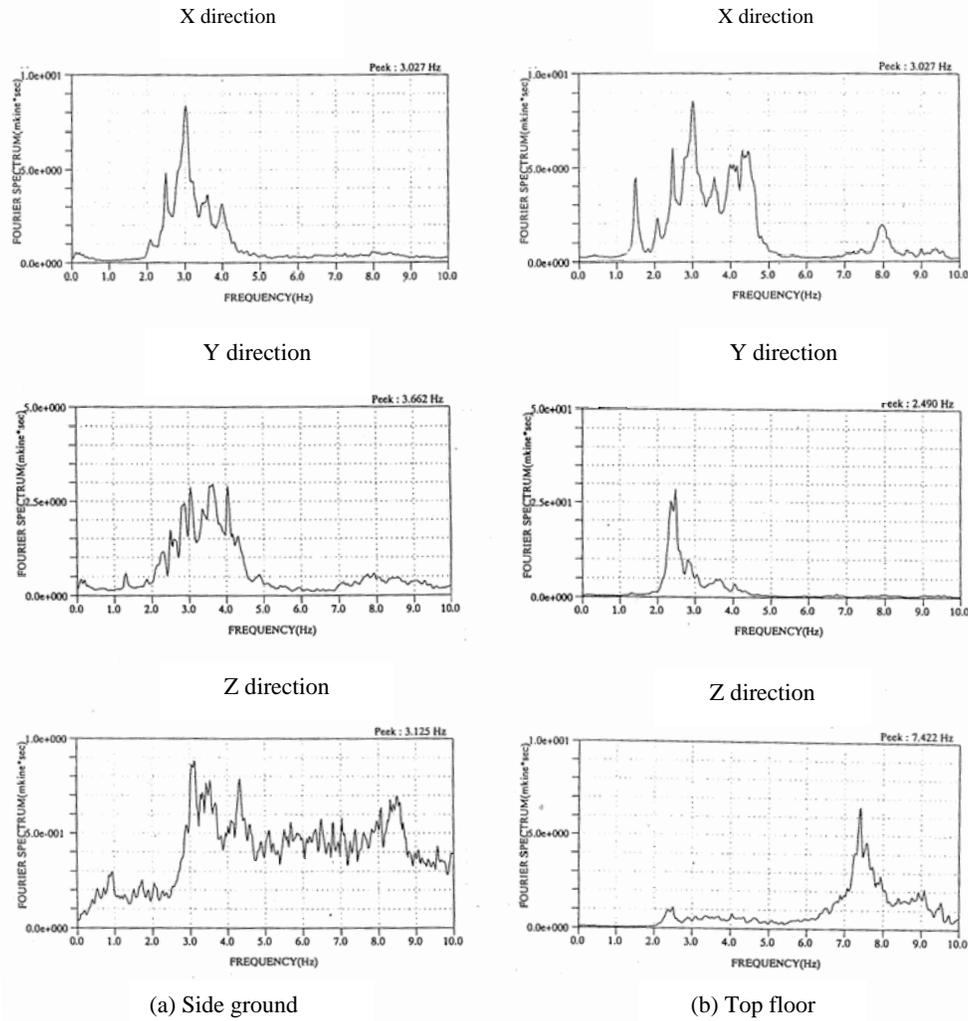


Figure 5. Fourier spectrum on the side ground and top floor of M building

15 channels. Therefore, as for the B house which resonance phenomenon occurs in, a big vibration occurs in about 9 times of the M house as well. (15 channels reference of the Figure 2 and the Figure 3)

About the M building. When the inclination of the mountain of the upper step (amplitude ratio) of the figure of the Figure 5 is seen, the 3.0Hz neighborhood of the frequency of vibrations that the X-Y direction spread from the M highway bridge comes off the mountain of peak, and considers that resonance phenomenon doesn't occur. Next, the spectrum figure of the roof is compared with the ground around the M building. (Figure 5 , reference) the one for the vibration tendency in the horizontal direction is both 2.5-4.5Hz neighborhood, and it is both in tendency. A vibration around the M building has more than one peak, and it can be said that it is the tendency to be different from the M

building roof's having peak in about 7.4Hz about the frequency of vibrations element in the up-down direction.

The 7.4Hz dish towel of the frequency of vibrations element of the M building roof is thought the characteristic frequency of vibrations of the floor. Therefore, because it is close to the M highway bridge, the vibration of the M building can be thought to vibrate directly due to the vibration in the horizontal direction which occurs from the solid bridge. And, the comparatively higher frequency of vibrations (the possibility of the characteristic frequency of vibrations of the floor has 7.4Hz) than the main frequency of vibrations element (about 3.0Hz) that it spread excels in the up-down direction.

CONCLUSIONS OF MEASUREMENT

It becomes the following when the knowledge which could get it by this research is put together.

A main vibration influence to give to private house is the running vibration of a big car to run through the M highway bridge. Specifications in the spectrum disposal are shown in the following Table 1.

A vibration to spread to the private house in the neighborhood is the vibration of the beam, and that characteristic frequency of vibrations is about 3.0Hz in the phenomenon of above one. The vibration of the beam spreads, and the X direction causes resonance phenomenon, and vibration greatly as for the B house. The resonance phenomenon doesn't occur through the vibration of the beam spreads in the M house which adjoins it. As for the M building, resonance phenomenon with the house doesn't occur in the horizontal direction through the vibration of the joint passage can be confirmed with the vibration of the beam a little. But, the up-down direction has the possibility that the characteristic frequency of vibrations of the floor excels by the place. The characteristic frequency of vibrations of the private house of three houses is as the next. B house: 3Hz, 4.3Hz (X direction) and 3.6Hz (Y direction) M house: 4.4Hz (X direction) and 5.3Hz (Y direction) M building: 1.5Hz, 4.5Hz (X direction) and 2.4Hz (Y direction). The vibration sense evaluation of the private house of three houses is as the next. B house: area of working space M house: area of precise working M building: area of precise working

Table 1. Natural frequency of the house (horizontal component)

Content	X direction	Y direction
B house	3.0 Hz , 4.3Hz	3.6Hz
M house	4.4Hz	5.3Hz
M building	1.5Hz , 4.5Hz	2.4Hz

SIMULATION ANALYSIS FOR M HIGHWAY BRIDGE

Purpose

Simulation analysis is enforced for the result of vibration investigation enforced with a purpose of making the factor that vibration of a car to run through M highway bridge exerts an influence of vibration on the nearby private house clear, and analyzed about the vibration factor of the private house examination.

Simulation analysis by the two dimensional FEM model

It was modeled based on data (the estimated characteristic frequency of vibrations) which could get a highway bridge and a house more than vibration investigation, and a two dimensional FEM model was built with the ground model, and a vibration analysis (compulsory exciting analysis) was enforced. It was counted backward to reproduce the result of investigation for which to could get in the ground beside the P37 pier, and exciting force in case of that was set up. The comparison of the result of investigation and the result of an assembly hall was

done by the vibration level value in the 1/3 octave band center frequency.

Terms of an analytic model and terms of analysis

Analytic model. The analytic model figure of the two dimensional FEM model is shown in the Figure 6. Rigidity and mass were adjusted in let's with the first characteristic frequency of vibrations in the characteristic frequency of vibrations 3.6Hz for the estimation in the horizontal direction which can get it than the result of the vibration investigation, and modeling of the house was set up. A model was built about the highway bridge based on the drawing, and the adjustment of the spring value was made to be the characteristic frequency of vibrations 3.0Hz about the beam for the estimation for lead value which it can get than the mass which it could get from the top of the drawing, and the vibration investigation. The ground model was estimated more than the result of boring investigation of the point concerned, and set up.

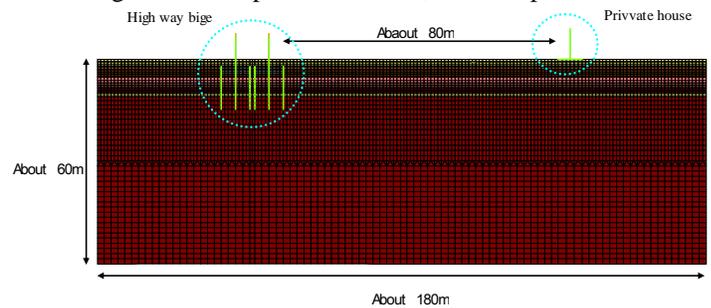


Figure 6. Analytic mode of the two dimensional FEM model

The ground model. The ground model was set up as a result of boring investigation enforced in the neighborhood of the point concerned. Used boring data was made boring name (H-10) mentioned in the inquiry of investigation document. The estimation of the S wave speed went by using the ceremony shown in the part of calligraphy which is showed a road bridge. As for the P wave speed, because it knew that about the surface of the earth side had a underground water place more than boring data, it was supposed the whole layer saturation, and the propagation speed 1500m/s of water was taken. The ground model set up in the Table 2 is shown.

Table 2. The parameter of the ground model

Depth (m)	Thick layer (m)	N value	Poisson's ratio	Unit weight (tf/m ³)	Vp (m/s)	Vs (m/s)	h (%)
0.00 ~ -1.80	1.80	22	0.500	1.73	1500	0	5.0
-1.80 ~ -3.30	1.50	2	0.500	1.73	1500	0	5.0
-3.30 ~ -5.30	2.00	3	0.500	1.65	1500	0	5.0
-5.30 ~ -6.80	1.50	11	0.500	1.60	1500	0	5.0
-6.80 ~ -8.30	1.50	4	0.500	1.60	1500	0	5.0
-8.30 ~ -9.80	1.50	2	0.500	1.65	1500	0	5.0
-9.80 ~ -10.80	1.00	4	0.500	1.65	1500	0	5.0
-10.80 ~	50	50	0.500	1.65	1500	0	5.0

Terms of analysis. Terms of analysis are shown in the following. An analytic technique: The exciting power to reproduce the observation record for which to be the closest to the way of answering. The analytic frequency of vibrations: 0-20Hz. The analytic model: two dimensional FEM model. The exciting

power: exciting point as to complex reply method in the frequency of vibration area is countered backward. A position of exciting, the center master of evaluation: 1/3 octave band of the result are vibration levels in the enter frequency.

Grasping of the propagation character of the ground

The calculation of the dispersion property of Rayleigh wave was done with a purpose of grasping the propagation character of the ground model set up.

The result of the dispersion property. The distributed curve of the group velocity is shown in the Figure 7. The amplitude distribution mode of Rayleigh wave in the ground direction is shown in the Figure 7.

About a result

As for the ground that airy-look was presumed to pay attention to the distributed curve (Figure 7) of the group velocity with the first mode with 5.8Hz the second mode near here 13.5Hz and which was set up, it knows a vibration to spread easily and not to decline easily around this frequency of the thing in the ground. The spread of the vibration from the position where be deep is expected in the depth from 8m to 9m when amplitude in the horizontal direction is comparatively big and there is a vibration source (for example, in such cases as the pile foundation) in the ground when it pays attention to the amplitude distribution (Figure 8) of Rayleigh wave in the ground direction, too.

It can't think that it has resonance phenomenon by three conditions of the highway bridge-ground private house from this examination by the vibration investigation in advance though excellence was seen together in vibration source side- highway bridge vibration accepted side of private house in 3-4Hz and it was excepted to have the character which made it spread in this neighborhood as for the ground as well of the vibration.

About the setup of the ground model by this examination, the result of the distributed character of the ground can be thought more investigation (for example, in such case as the P.S matter layer) to be a tail at writing brush night when great difference isn't seen and the ground model is set up again even if it is compared with a result of boring investigation in the closest position to the point concerned though it is greatly decided by how to set up the ground model. Because the big factor which

should be changed didn't specially exist about the set point of the ground. As for the future examination simulation analysis by the two dimensional FEM model as well, it decided to be done by using the ground model adopted by this examination.

Simulation analysis by the two dimensional FEM model

It was modeled based on data which could get a highway bridge and a house more than vibration investigation, and a two dimensional FEM model was made with the ground model, and compulsory excitation analysis was enforced. It was counted backward to reproduce the result of investigation for which to have it with a ground around the P37 pier, and exciting force in case of that was set up.

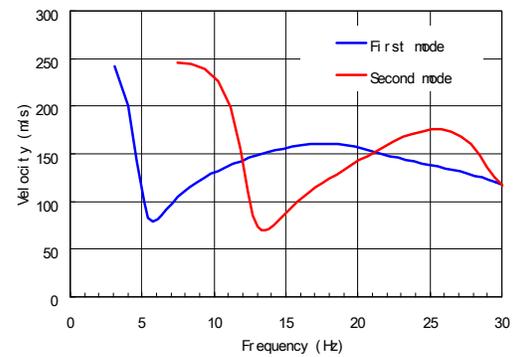


Figure 7. Distributed curve of the ground velocity

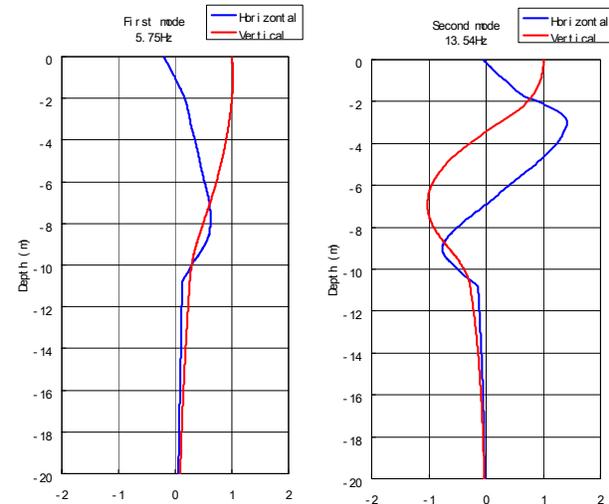


Figure 8. The amplitude distribution mode of Rayleigh wave

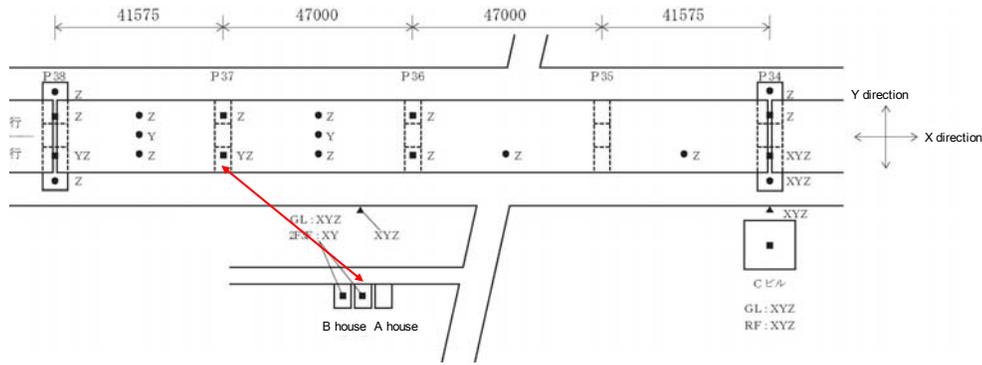


Figure 9. The position relations of the highway bridge and the private house

The physical relationship of the highway bridge and the private house and an analytic model section

The position relations of the highway bridge and the private house are shown in the Figure 9. A private house is located in about the center between the pier of the highway bridge, and the pier it can think to give a private house a great influence exists in two (P36 and P37). However, when the vertical vibration which it could get with a ground around the pier of P36 and P37 was compared, great difference was seen, and it was a ground around the pier as an analytic examination section from person thing, and moved to the section which went from P37 that vertical vibration measurement was being done with the horizontal to the private house.

The output point of the analytical result

It was set up as a position to compare it with a result of investigation as shown in the ground plan.

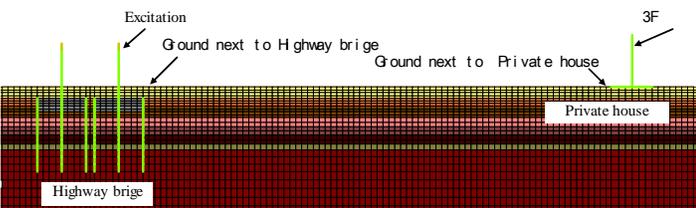


Figure 10. The cross section of the analytical model

A result with only a vertical excitation direction

It acted the excitation power in the vertical direction on the end of the pier sky, and its result of investigation was compared an analytical one. The result in a position of a ground around the private house board mostly as a result of enforcing excitation analysis. However, as for the horizontal direction of a ground around the private house board, it became an underestimate. As for the vibration in the vertical direction, it thought that it could be imitated mostly, and went in the horizontal direction as well as 9.1 as a excitation power more than the examination of the private house three floors (the horizontal). The comparison of the result of an analysis and the result of investigation. Though

it grew big and approached a result of investigation, still a horizontal vibration in the ground around the private house keeps being an underestimate as that result. That tendency doesn't change with 9.1 though a vibration is a little big as for the result of the private house the third floor as well.

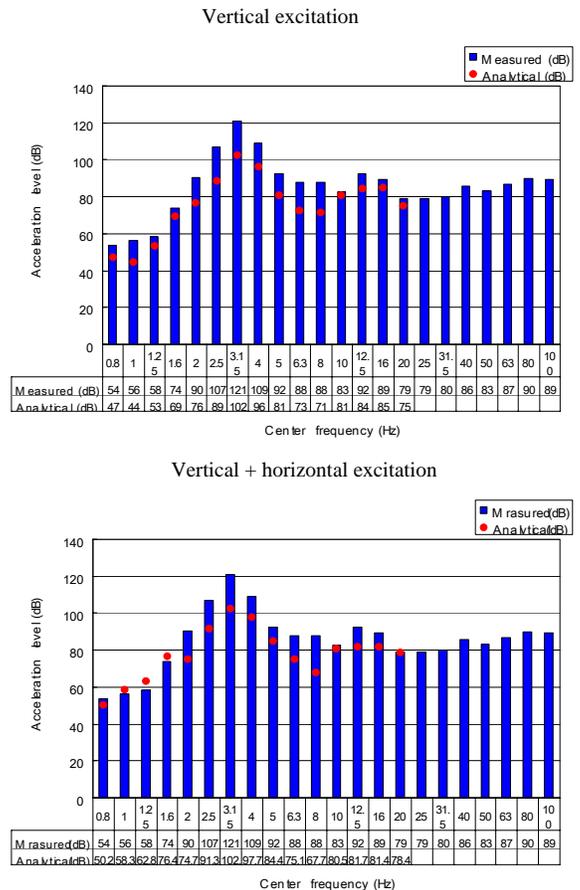


Figure 11. Relation between analytical result and measured result

CONCLUSIONS

It found that the neighborhood was the frequency that a vibration spread easily with first mode with 5.8Hz, the second mode 13.5Hz by using the ground model set up as a result of calculating the distributed character of the ground. It thinks that resonance phenomenon of three conditions of the highway bridge-ground-private house expected from a little high place.

The excellent frequency of vibrations as 3-4Hz comparison of the excellence frequency of vibrations of the highway bridge, private house vibration investigation result in the ground, in the beginning is hard to think about.

REFERENCES

K. Hayakawa, I. Nakaya, K. Tanaka, T. Nishimura (2007), "The analysis of the spread mechanism of a low frequency ground vibration to spread from the highway bridge made of steel," 3rd International symposium environmental vibrations ISEV 2007, (In press)

Tokunaga, N., Iemura, H., Nishimura and Mori, A., K. Hayakawa, T., (1997) "A study on propagation mechanism of the vibration due to road traffic," Journal of the Eastern Asia Society for Transportation Studies, Vol.2, No.6, pp.2013-2030.