Ngai province, propose appropriate values for designing works" ” master thesis, Hanoi University of Mining and Geology.
[4] Nguyen QuangPhich (2000), Theory of solid and solid mass mechanics, University of Mining and Geology, Hanoi.
[5] Nghiem Huu Hanh (1997), Rock Mechanics, Publishing House, Hanoi.
[6] History of Hoek-Brown's destructive standards and the latest version 2002 - Translation of Master of Technology Nguyen DucToan Institute of Transport and Technology, 2006.
[7] Barton N (1995). Design of Tunnels using NMT and Verification with UDEC-BB.
[8] Hoek-Brown Failure Criterion (2006) Edition by Evert Hoek, Carlos Caranza-Torres and Brent Corkum.
[9] Hoek E. and Brown E.T (1980), Undergrown excavation in rock, London.
[10] Hoek E. and Brown E.T (1983), Strength of jointed rock masses,
[11] Hoek E. and Brown E.T (1988), The Hoek-Brown failure criterion a 1988 apdate.
[12] Ta Minh Duc (2003), "The study evaluates the applicability of the Hoek-Brown standard to determine the rock characteristics in Vietnam, take some blocks of hydroelectric foundation for example” master thesis, Hanoi University of Mining and Geology.
[13] Roclab - User's guide for Rock mass Strength analysis using the Hoek-Brown criterion software, 2002.
[14] Vietnamese Standard 4253: 2012 on Irrigation Works - Hydropower Projects - Design Requirements.

DOWNHOLE SEISMIC TESTING TO DETERMINE ELASTIC PARAMETERS OF THE GROUND FOR ANTI - SEISMIC DESIGNS: A CASE STUDY IN THE INDUSTRIAL ZONE VUNG RO, PHU YEN

Bui Truong Son, Vu Thai Linh
Hanoi University of Mining and Geology, Vietnam
Corresponding author' Email: buitruongson@humg.edu.vn

Abstract: This paper presents an application of downhole seismic testing to determine elastic factors of the ground for anti-seismic designs. The research result illustrates elastic factor including dynamic elastic modulus (E), shear modulus (G), bulk modulus (Kd), Poisson ratio (υ) will be determined from the work of insitu tests in downhole seismic testing.

Keywords: downhole sesmic; shear modulus; shear modulus; bulk modulus; Poisson ratio.

1. Introduction

At present, it is considered that the constructions in industrial parks do not need to account for the earthquake load. But after the impact of earthquake shakes off the South Central Coast in 2005, the system of high buildings in Ho Chi Minh City shook, the anti-seismic designs for high buildings have been taken into account. Some investors of large projects have requested the design of buildings to be subjected to earthquakes, especially large load works.

In anti-seismic design, there are many methods that can determine the parameters of the ground. One of these methods is to measure the horizontal velocity (Vs) and longitudinal (Vp) waves by measuring downhole seismic along boreholes at the construction sites the horizontal velocity (Vs) and longitudinal (Vp) waves by measuring downhole seismic along boreholes at the construction sites. However, in reality in Vietnam, downhole seismic testing in boreholes has been recently applied and no finished procedure has been researched by domestic scientists. Therefore, the study applied downhole seismic testing into bore holes to calculate the ground parameters for the design of the anti-seismic resistance is very necessary.

The results of several authors, such as Castro & Carino, 1998, Vipulanandan & Garas, 2008, show that there is a relationship between dynamic elastic modulus, bulk modulus, Poisson's coefficient of the material and vertical velocity values (Vp) and horizontal waves (Vs).

- Dynamic elastic modulus E:

$$E = \frac{\rho V_s^2 (3V_p^2 - 4V_s^2)}{V_p^2 - V_s^2} \quad (1)$$

- Shear modulus G:

$$G = \rho V_S^2 \quad (2)$$

- Bulk modulus K_d :

$$K_d = \rho(V_P^2 - 4/3V_S^2) \quad (3)$$

- Poisson ratio υ:

$$\upsilon=1/2[(1-(2(V_S/V_p)^2)/(1-(V_S/V_p)^2)] \quad (4)$$

Thus, if we have equipment that determines the the horizontal velocity (Vs) and longitudinal (Vp) waves by measuring downhole seismic along boreholes at the construction sites, then the elastic parameters of the ground can be determined.

2. Testing

When testing, there is only a given borehold, the cost is not as high as crosshole seismic. Basing on the geological features of the study area, the drilling methods, selection of the downhole seismic testing to determine the longitudinal wave velocity P and the transverse wave S for the calculation of parameters seismic resistance for the study area is most reasonable.

The basic data acquisition system consists of the following:

- Energy sources: These energy sources are chosen according to the needs of the survey, the primary consideration being whether P-wave or S-wave velocities are to be determined. To produce an identifiable S-wave, the source should transmit energy to the ground with a particle motion perpendicular or transverse to the axis of the survey.

- Receivers (geophone - GP) consisting of two groups of three-dimensional geophone reception wave sequentially on the wall of the casing tubes under the hole. The spacing between the two sets of GPs is not too far apart to accommodate the actual survey in the soil layers. CThe position of the wave receivers is sequentially from top to bottom and spaced by a certain distance depending on the survey requirements or stratigraphic conditions of the survey area.

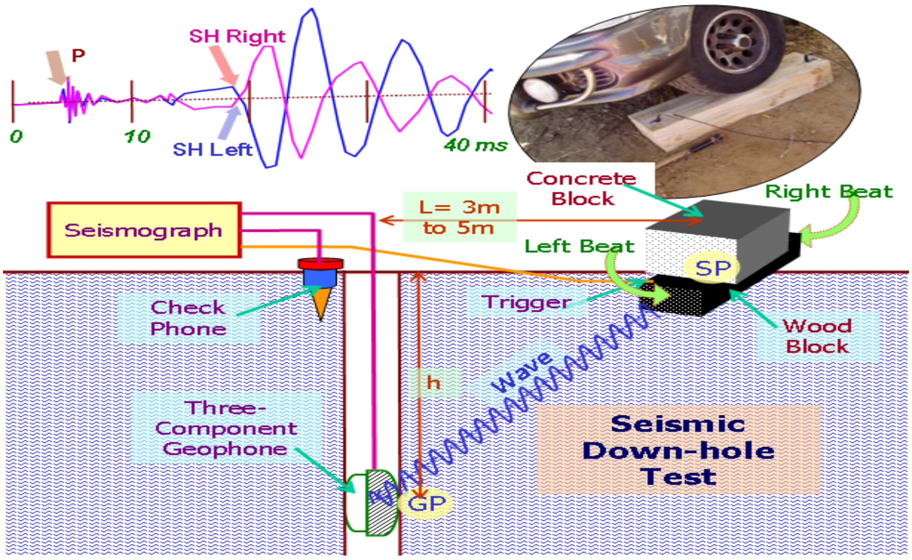


Fig. 1. Diagram of downhole seismic testing

- The preparation of boreholes and completion of boreholes prior to measurements is critical to the success or failure of the test. The poor connection between the casing tube and wall will result in delayed arrival time and signal degradation, especially for high-frequency P-wave. If the raw material environments (eg sand, cobble, etc.) occur when the drilling loss is too high, the amount of mortar that is too thick can affect the S wave transmission time and velocity properties.

The process of recording is done by arranging the sources at the appropriate distance, the first signal recorder at the mouth of the drilling hole, the second recorder lying on the ground. Arrangement of the combination parallel to the axis of the transverse direction if possible. Keep the recorder in the hole. Survey the equipment inspection and determine the recording time

The calculation of the longitudinal and transverse waves in the longitudinal wave measurement method into boreholes is as follows:

- Enter the information on the petrographical composition by drilling results, coordinates, position (if any).

- Enter the parameters of the borehole elevation EG, the height of the anvil ES, the depth of each geophone in the hole DG, the distance from the center to the center of the bore hole X. Calculate the distance between the source and the anvil LR as the following:

$$L_R = \left[\left(E_S - E_G + D_G\right)^2 + X^2\right]^{0,5} \tag{5}$$

- Select the P and S wave time on the tape, calculate the P and S wave velocity directly according to the following formula:

$$V = (L_{R2} - L_{R1})/\Delta T_{(R2 - R1)} \tag{6}$$

In which: L_{R2}, L_{R1} - Straight-line slant distances from source to geophone at the depth d_{i+1} và d_i; $\Delta T_{(R2 - R1)}$ - The difference in time between the source and the receiver at two positions d_{i+1} và d_i; V- The velocity of propagation of the soil layer between the two locations is d_{i+1} and is located in the hole.

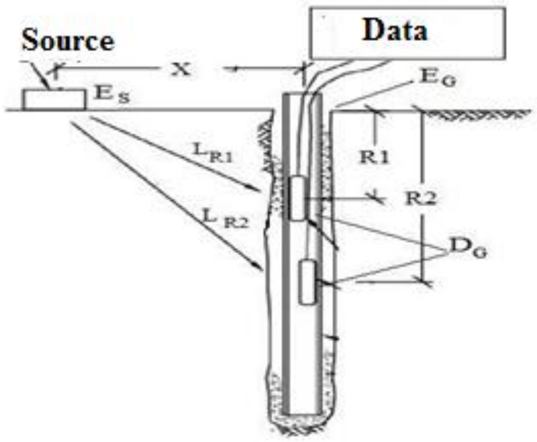


Fig. 2. Diagram calculating in the downhole seismic testing method

3. Results applied in Vung Ro Industrial Zone, Phu Yen

3.1. Overview of geological characteristics of Vung Ro industrial zone

The Vung Ro oil refinery project is located in the geographical coordinates of $12^0$52'-$12^0$56' North latitude and $109^0$22'-$109^0$26'East longitude; the total area of land used is 538ha, of which 404ha of land for the factory construction, 134ha for the construction of Bai Goc port and in addition 500 to 1.300ha of marine area is in use.

The project is located in Hoa Tam commune, Dong Hoa district, Phu Yen province. Vung Ro Oil Refinery project belongs to Nam Phu Yen coastal economic zone. The project is located near the Bai Goc seaport, 10km from the North of Vung Ro Bay, 15km south of Tuy Hoa Airport and 35km south of Tuy Hoa City.

Based on the geological survey results of the site, the geological map of the Geological Division of Vietnam, 1996, the geological map of the Ban Nham, the sheet group of Tuy Hoa, with the scale of 1: 50.000, the Department of Management Vietnam, 2007; Geological map of coastal sand in Phu Yen province, scale 1: 50.000. The geological structure of the research area is divided into three structural layers: the upper structure, the middle structure and the lower structure.

The top layer is a collection of sedimentary deposits of river sediments, river-sea sediments sediments, sediments, marine-marsh sediments, wind sediments and Dong Thanh formation, Hoa Tri formation, Hon Chong Formation, Thach Ban Formation. With the age from late Pleistocene to Late Holocene.The topsoil includes sand, sand mixed with gravel, quartz sand with silt, silty-sandy clay ... some also contain shells, and humus… due to the effect of formation conditioning.

3.2. Study results

In the survey area, downhole seismic testing was applied at 3 boreholes BH04, BH20, BH41, BH55 (Figure 3).

The tables 1,2,3, 4 and 4 (a, b, c, d) shows the results of longitudinal and transverse wave velocity measurements in the boreholes, the elastic parameters of the ground are calculated according to formulas 1,2,3 and 4.

Tab. 1. Results of BH04 hole elasticity parameters

Depth, m		Velocity, m/s		γ	G	E	Kd	ν
From	To	Vp	Vs	(g/cm^3)	(kG/cm^2)	(kG/cm^2)	(kG/cm^2)	
0	2	788	234.5	2.65	145.72	423.013	1451.2	0.45
2	12	810.82	286.86	2.66	218.89	625.346	1456.91	0.43
12	30	1511.45	611.64	2.65	991.37	2779.98	4732.04	0.40
30	38	2138.2	756.92	2.64	1512.53	4320.89	10053.1	0.43
38	42	2550.54	835.3	2.69	1876.88	5405.16	14996.6	0.44
42	50	2177.57	744.7	2.65	1469.63	4214.25	10606.3	0.43
50	60	2223.87	405.32	2.7	443.57	1315.46	12761.7	0.48

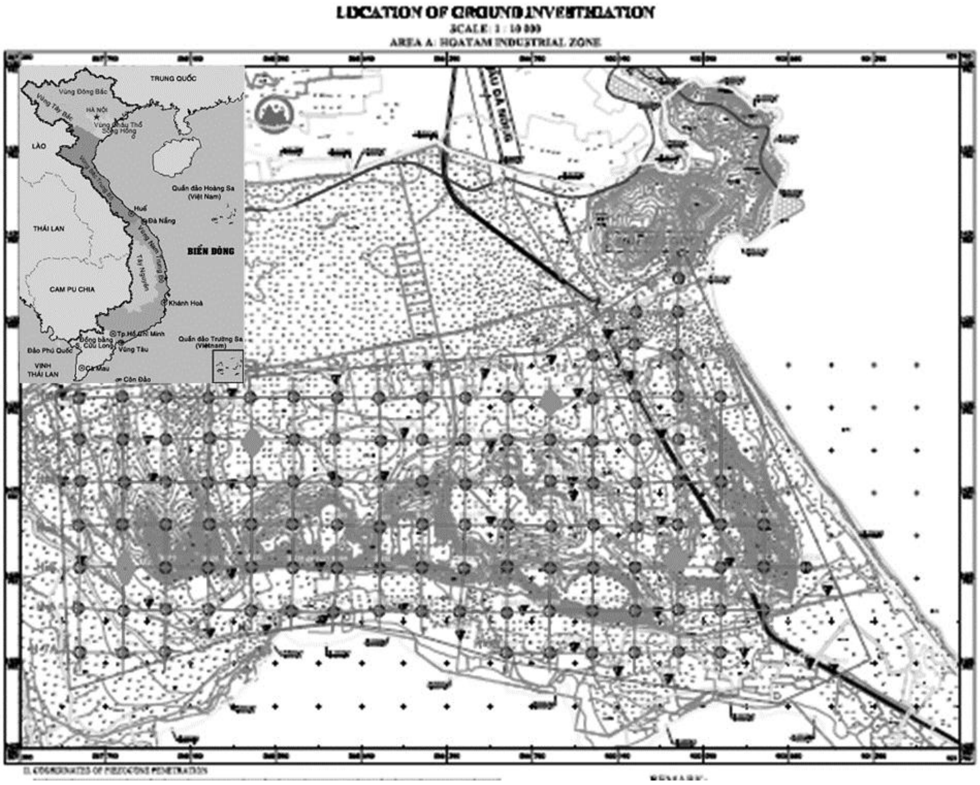


Fig. 3. Layout of the borehole positions
implemented by downhole seismic testing method

Comment: In the depth range 0-2m, the average velocities Vp = 788 m/s, Vs = 234.5 m/s corresponding to the filling gravel layer level above the hydrostatic level shows the rate of wave propagation in the filling layer is usually very small.

At a depth of 2-10m, the average value Vs = 810.82 m/s, Vs = 286 m/s corresponds to poorly graded sand, grayish blue, grayish gray, moderately firm.

From a depth of less than 10 meters, the mean vertical waves Vp and horizontal waves Vs are gradually increased with respect to the density of the soil layers. We see that the longitudinal V_P velocity values and V_S transverse velocity variations are not much in the same class, and the boundaries between those values change dramatically.

The results of the downhole seismic testing of borehole are the same stratigraphy as those of the borehole logging.

Tab. 2. Results of BH20 hole elasticity parameters

Depth, m		Velocity, m/s		γ	G	E	Kd	ν
From	To	Vp TB	Vs TB	(g/cm^3)	(kG/cm^2)	(kG/cm^2)	(kG/cm^2)	
0	2	647.26	215.08	2.66	123.05	353.88	950.33	0.44
2	10	1778.89	654.4	2.64	1130.55	3214.72	6846.74	0.42
10	32	1387.68	392.99	2.67	412.36	1201.12	4591.69	0.46
32	50	2397.48	645.96	2.72	1134.96	3316.04	14121.04	0.46
50	54	2218.6	713.28	2.64	1343.15	3874.61	11203.71	0.44
54	60	2533.68	809.07	2.7	1767.40	5101.53	14976.20	0.44

Comment: In the depth range 0-2m, Vp = 647m/s, Vs = 215.08 m/s, from 2-6m Vp = 1778.89 m/s, Vs = 654.40 m/s the vertical velocity varies with the increase in depth, in which the most obvious boundary between the layers is the hydrostatic level, where there is a sudden change in the velocity of the ventilation zone. It has a velocity of several hundred m/s (usually <650 m/s) and a saturation zone> 1900 m/s. From a depth of less than 3m, there is wave velocity change clearly. Based on the vertical velocity graph (Vp) and the horizontal wave (Vs), we see that the geological drilling results are consistent with the results. Vertical velocity V_P values and V_S transverse velocity values are high in sandy layers with dense to very dense.

Tab. 3. Results of BH41 hole elasticity parameters

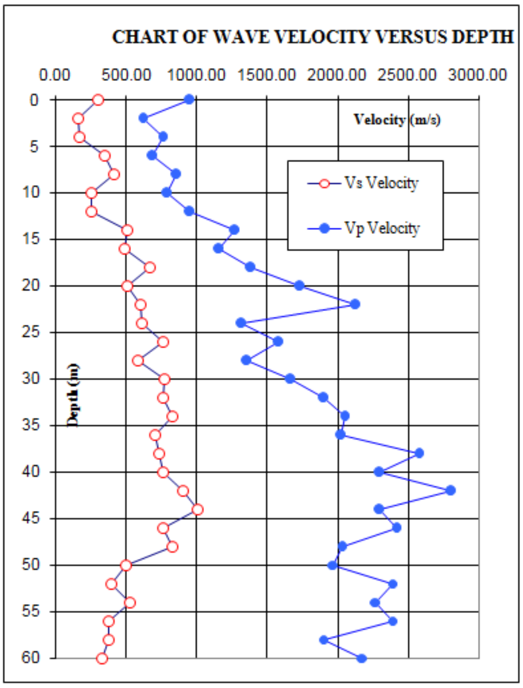
Depth, m		Velocity, m/s		γ	G	E	Kd	ν
From	To	Vp TB	Vs TB	g/cm3	(kG/cm^2)	(kG/cm^2)	(kG/cm^2)	
0	2	685.24	267.9	2.66	190.91	538.28	994.47	0.41
2	12	1647.7	380.7	2.66	385.52	1134.82	6707.65	0.47
12	30	2249.2	381.73	2.67	389.07	1155.66	12988.51	0.49
30	43	2587.19	439.82	2.66	514.55	1528.35	17118.78	0.49
43	46	3093.91	513.83	2.69	710.22	2110.51	24802.47	0.49
46	48	2190.3	460.86	2.68	569.21	1681.26	12098.12	0.48
48	60	2466.72	506.81	2.67	685.81	2027.19	15331.76	0.48

Comment: In the depth range 0-2m, the average wave velocity Vp = 685.24 m/s, Vs = 267.90 m/s corresponding to the filling layer. From 2-8m, Vp = 1647.70 m/s, Vs = 380.70 m/s corresponding to the coarse sand layer. From 14 to 30m Vp = 2249.20 m/s, Vs = 381.73 m/s corresponding to fine sand layer, medium dense, we see that the longitudinal wave has greater variation than the horizontal wave in the same degree. In depth, variable poisson coefficients are often small at different depths. At the boundaries of the sand layers, the value of the elastic parameters changes sharply.

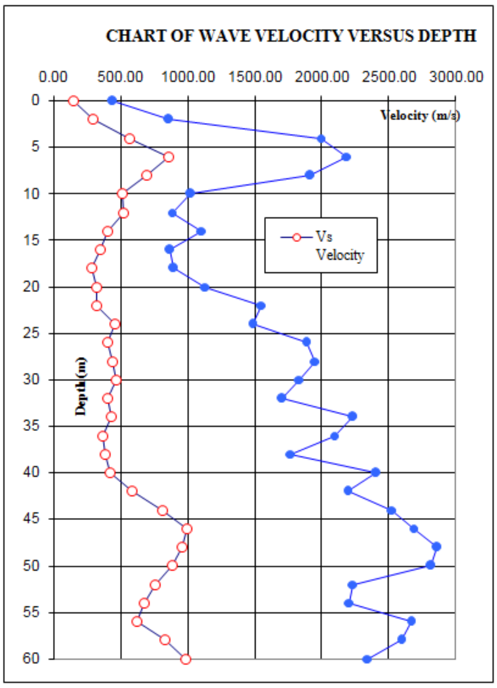
Tab. 4. Results of BH55 hole elasticity parameters

Depth, m		Velocity, m/s		γ	G	E	Kd	ν
From	To	Vp	Vs	(g/cm^3)	(kG/cm^2)	(kG/cm^2)	(kG/cm^2)	
0	2	242.21	120.01	2.67	38.45	102.85	105.36	0.34
2	7	1606.88	667.5	2.67	1189.64	3320.81	5307.93	0.40
7	43	1836.98	559.51	2.67	835.85	2422.07	7895.44	0.45
43	44	1745.03	372.97	2.68	372.81	1100.57	7663.87	0.48
44	60	1797.25	428.61	2.66	488.66	1436.51	7940.54	0.47

In the depth range 0-2m, the average wave velocity Vp = 242.21m/s, Vs = 120.41m/s corresponding to the fill layer. From 4-8m, Vp = 1666.88 m/s, Vs = 667.50 m/s corresponding to the coarse sand layer. From 10 to 42m Vp = 1836.98 m/s, Vs = 559.51 m/s, the wave velocity in this position increases with the depth. Based on the vertical velocity graph (Vp) and the horizontal wave (Vs), we see that the geological drilling results are consistent with the results. At a depth of 0-2m, the value of the elastic parameters at this location is very small. At a depth of 10-26 m, the longitudinal wave value is the largest, proportional to the state of the soil here.



(a)



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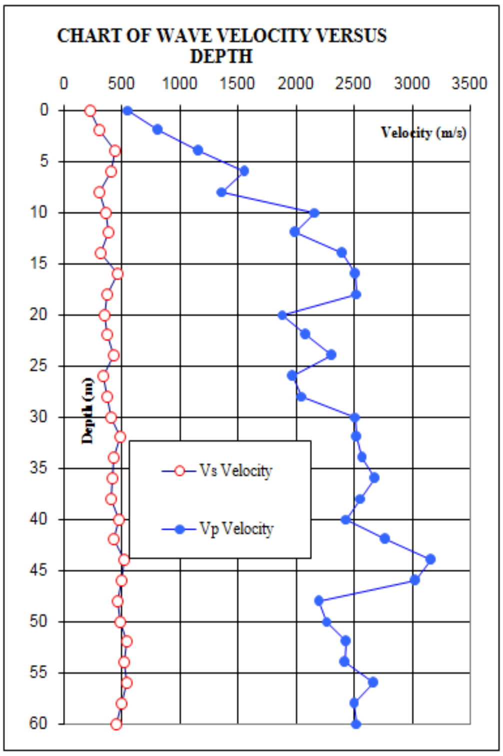
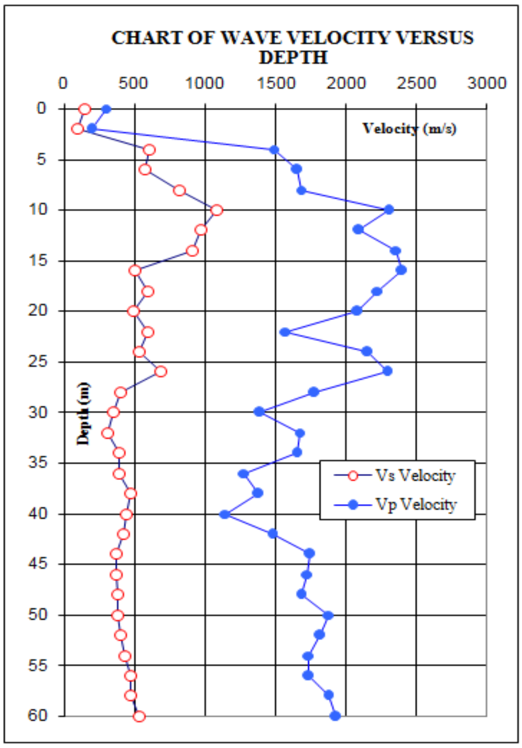


(c)



(d)

Fig. 4. Vp and Vs variation in depth
a. Borehole BH04; b. Borehole BH20; c. Borehole BH41; d. Borehole BH55

4. Conclusion

From the results of the study, author analysis has some conclusions as follows:

- The downhole seismic testing has proved to be advantageous in determining the longitudinal and transverse wave velocities compared to crosshole seismic testing. The longitudinal and transverse wave velocity values in each soil layer corresponding to the stratigraphy of the hole. From the longitudinal and transverse wave velocity values, the authors calculated the elastic parameters of the soil, including elastic modulus, poisson coefficients, shearing modulus and bulk modulus.

- The results of research and crosshole seismic testing to the hole confirmed the importance of the application of the method of seismic hole in the design of the anti- seismic for buildings

References

[1] ASTM: D4428 / D 4428M, Standard Test Methods for Crosshole Seismic Testing.

[2] ASTM: 7400-08, Standart Test Methods for Downhole Seismic Testing.

[3] Drilling rig surveying the geology of Vung Ro Industrial Park, Phu Yen.

[4] Geological Division of Vietnam (1996), Geological map of Nhan Van, Tuy Hoa paper group, 1: 50,000 scale.

[5] Mai Thanh Tan (2011), Seismic Exploration, Transportation Publishing House, Hanoi.

[5] Ministry of Natural Resources and Environment (2011), Circular No. 04/2011 / TT - BTNMT: Regulation on Seismic Techniques in Basic Geological Survey of Minerals and Geology of Works, Hanoi.

[7] Nguyen Quang Dung, Vu Dinh Loi (2013), Ground vibration forecasts for Ho Chi Minh city metro traffic, Journal of Transportation, 04/2013

[8] Nguyen Quang Dung (2013), Rescuing vibration and reducing vibration in the background due to the exploitation of the subway system, PhD thesis in Science, Military Academy.

[9] Nguyen Thanh Trung (2016), Resistance Design, Pier Publishing, Publishing House, Hanoi.

[10] Trinh Viet Bac et al. (2011), "Ground condition influenced by the earthquake effect west of Hanoi", Institute of Geology-Vietnam Academy of Science and Technology, Hanoi.

[11] Vietnam National Standard 9386-2012, Design of earthquake resistant works, Ministry of Science and Technology.

[12] Vietnam Water Management Department (2007), hydrogeological map of coastal sand in Phu Yen province, scale 1: 50,000.