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Acoustic Characteristics of Gravel Sediment: Application of the BICSQS model

Seom-Kyu Jung †, Dong Wan Lee, Dong-Hyeok Shin, Yong-Kuk Lee, Bok Kyoung Choi, Bong-Chae KIM and Byoung-Nam Kim (Maritime Security Research Center, Korea Institute of Ocean Science and Technology)

1. INTRODUCTION

Acoustic properties such as phase velocity or attenuation of ocean sediment have been studied by many researchers because it affects acoustic propagation in the under of ocean. Theoretically, Biot's theory is well known for explain the phase velocity and attenuation of porous medium like ocean sediment [1]. After that, BISQ model which considered grain to grain contact physics is developed by Dvorkin and Nur [2]. And BICSQS model which adds grain contact squirt flow and viscous drag to BISQ model is worked out by Chotiros and Isakson [3]. By these models, behavior of the phase velocity and attenuation of ocean sediment can be explained. Until a recent date, sand sediment is mainly investigated, it is necessary to study about gravel sediment.

In this study, the phase velocity and attenuation of gravel sediment are investigated using experimental measurement and the BICSQS model. The gravel sediment has larger grain size than the sand sediment, so input parameters of BICSQS model are also different. For this purpose, we compared with laboratory experiment data and numerical computation model. The laboratory experiment is carried out at frequency range 40-150 kHz in fresh degased water and measured phase velocity and attenuation of gravel sediment. To explain this measurement, we applied the BICSQS model. Through these results, tendency of phase velocity and attenuation in frequency domain are discussed.

2. EXPERIMENTAL MEASUREMENT

In order to measure the phase velocity and attenuation of gravel sediment, we carried out the laboratory condition experiment. Fig. 1 shows experimental setup. The gravel sediment sample was placed in water tank filled with fresh degased water(t=26 ℃). Size of water tank is 1200×450×600 (mm) and gravel sample was put in the Lucite box which has thin thickness wall enough to ignore the low frequency acoustic wave propagation used in this experiment and the thickness of gravel sediment sample was 50 mm. Acoustic wave is transmitted by spherical transducer (Gearing & Watson D/70) and received by hydrophone (B&K type 8103). The transmitting transducer and receiving hydrophone were each 50 mm and 5 mm away from the front and back of gravel sediment sample box. Transmitted signal was generated by function generator (Agilent 33220A) frequency range 40-150 kHz. The received signal was performed a fast Fourier transform (FFT) to obtain frequency spectrum and phase information. Using these data, we work out phase velocity and attenuation of gravel sediment experimentally. These results were applied the BICSQS model. Table 1. shows BICSQS model parameters of gravel sediment. The diameter of gravel sediment grain was controlled by testing sieve which value is 3.35±70 mm and porosity is 45%. Compared with sand sediment, the porosity is similar but grain size much larger than grain size of sand sediment. It affects the difference of phase velocity and attenuation between gravel and sand.

3. RESULT AND DISCUSSION

Fig. 1 is phase velocity of gravel sediment. It shows good matching between experimental measurement and BICSQS model at 40-150 kHz. Our measurement value of phase velocity at frequency range 40-150 KHz is 1580-1630 m/s. It is

Table. 1 Parameter values of BICSQS model.

Parameters	Value
Bulk properties	
β, porosity	0.45
ρ_r, grain density (kg/m^3)	2650
ρ_f, fluid density (kg/m^3)	998
K_r, grain bulk modulus (GPa)	36
K_f, fluid bulk modulus (GPa)	2.4
Fluid motion	
η, fluid viscosity (kg/m-s)	1.0×10^{-3}
κ, permeability (m^2)	8.114×10^{-8}
a, pore size (μ)	1.939×10^{-3}
α, Tortuosity	2.589
Frame response	
μ, frame shear modulus (GPa)	1.976×10^{-2}
K_y, frame bulk mod. difference (GPa)	0.3
f_k, bulk relaxation frequency (kHz)	30
f_k, shear relaxation frequency (kHz)	80
a_1, Gap width	2.1×10^{-5}

bnkim@kiost.ac

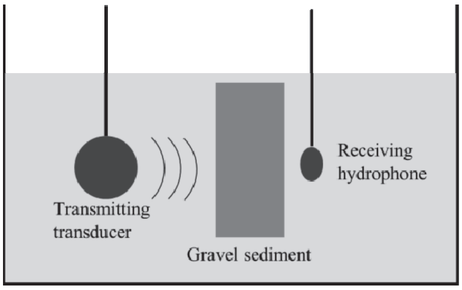

Figure. 1 Experimental setup.

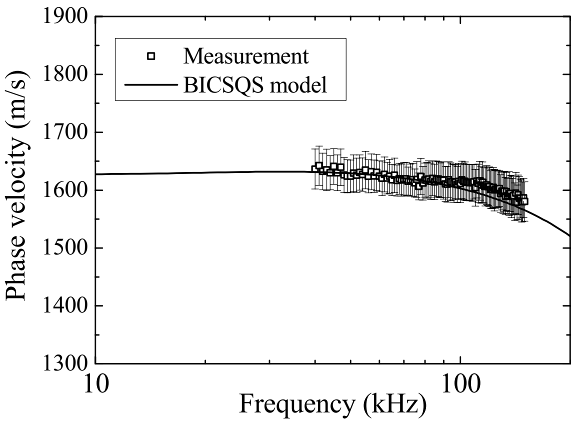

Figure. 2 Comparison of phase velocity in the experimental measurement and the BICSQS model.

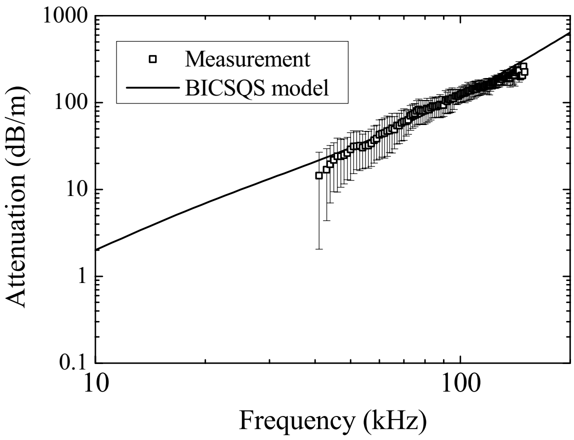

Figure. 3 Comparison of attenuation in the experimental measurement and the BICSQS model

even lower than sand sediment which has similar Porosity[4]. It seems that the grain size mainly affects measuring low phase velocity in this experiment. The measuring frequency is getting higher, the phase velocity has a downward tendency. This tendency start around 50 kHz, it is also lower than sand sediment. In the prediction of BICSQS model, the frequency is getting lower, the phase velocity has also downward tendency. So, we need to measure low frequency range (less than 40 kHz).

Fig. 2 is attenuation of gravel sediment. The BICSQS model and experimental measurement data have a good agreement. These results are the BICSQS model can explain the phase velocity and attenuation of the gravel sediment at frequency range 40-150 kHz.

4. CONCLUSION

The phase velocity and attenuation of gravel sediment are studied. The experimental measuring values are explained by the BICSQS model. At frequency range 40-150 kHz, the measuring values are good agreement with the BICSQS model. Through this result, we figure out the BICSQS model can apply to expect phase velocity and attenuation of gravel sediment. In this study, the gravel sample doesn't include sand. This condition is different with natural ocean sediment. And we didn't get experimental measurement data at less than 40 kHz frequency range. So, we need more experiment at similar condition with natural ocean sediment and less than 40 kHz frequency range.

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