POISSON'S RATIO EVALUATION ON SILTY AND CLAYEY SANDS ON LABORATORY SPEICMENS BY FLAT DISK SHAPED PIEZO-CERAMIC TRANSDUCER

Laxmi Prasad SUWAL[1], Reiko KUWANO[2],

ABSTRACT: Recently flat disk shaped piezo-ceramic transducer has been developed for laboratory based researches. It enables to measure both compression and shear (P and S) waves in a single specimen at same stress and other physical state. Authors have evaluated the Poisson's ratio measuring elastic waves by flat disk shaped piezo-ceramic transducer on silty and clayey fine sands. The silty and sandy fine sands are prepared mixing silt and clay with Toyoura sand in several proportions. This paper presents the Poisson's ratio on several fine content sands by elastic wave measurement technique and compared with statically determined one including the effects of fine on its value.

Key Words: Poisson's ratio, fine content sand, Wave measurement, Laboratory test

INTRODUCTION

Poisson's ratio of the material reflects the transverse deformation characteristics. It is one of the prominent characteristics of materials on analysis of deformation behavior. It is generally defined as the lateral deformation due to application of load along longitudinal direction. This parameter is frequently used in several kinds of design and analyses in engineering field. Most materials have Poisson's ratio values ranging between 0.0 and 0.5. Material deformed elastically at small strains possessing constant volume would have a Poisson's ratio of nearly 0.5. Statically evaluation by monitoring axial and radial (vertical and horizontal) direction is popular amongst the researchers as the Poisson's ratio evaluation method. Precise local strain measurement is the major essential task in this task. Local strains are needed to be measured to minimize the effects of bedding errors and system compliance (Tatsuoka & Shibuya, 1992; Lo Presti, 1993; Tatsuoka and Kohata, 1995). Several researchers have developed a reliable technique for measuring local strain. Inclinometers were developed at the Imperial College of London (Burland and Symes, 1982). Local Deformation Transducer (LDT) was invented at the University of Tokyo (Goto, 1991). A pair of wave velocities (P and S) on identical specimen at same stress state is essential to compute the Poisson's in terms of wave velocity. Only few researchers had attempted to measure both P and S waves combining compression plate and bender element in laboratory (Brignoli, 1996; Lee, 2010). Bender-extender was adopted to measure both P and S waves on single specimen of sands in few years ago and Poisson's ratio was dynamically evaluated (Kumar and Madhusudha, 2010). Recently flat shaped disk type piezo ceramic transducer permitting to perform the tests on cemented as well as granular materials, Undisturbed as well as reconstituted samples has developed in the University of Tokyo (Suwal and Kuwano, 2010). This transducer is adopted in this study to evaluate both P and S wave velocities.

Sandy materials are often used as the filling materials in the embankment and other structures. Those

---

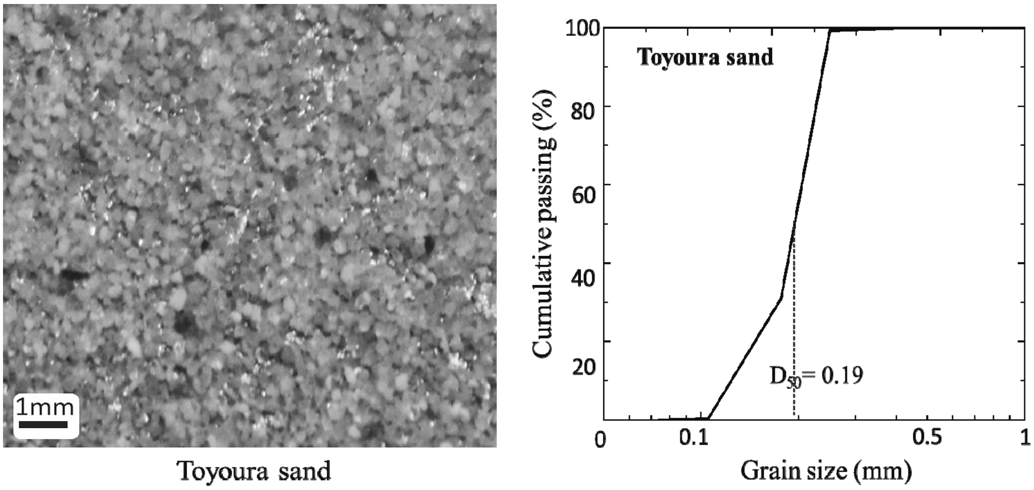
[1] Graduate Student, Department of Civil Engineering, University of Tokyo
[2] Associate Professor, Institute of Industrial Science, University of Tokyo

materials may have possibility of containing fines. The type and amount of fine affects significantly for altering mechanical properties. Resembling this condition, the laboratory based study has done to investigate the role of fines on fine sand. Toyoura sand, fine sand of mean grain size 0.19 mm, was mixed with the fines; non-plastic fines (DL-Clay) and Kaolin clay. The amount of the fines are thoroughly stirred with sand controlling its quantities ranges from 5 % to 15 % and was used for erecting the specimen of Φ75mm and height 150 mm. A series of laboratory tests was conducted on triaxial apparatus. The obtained results by local strain measurement and elastic wave measurement are presented here and the results obtained by both techniques are compared.

MATERIALS, APPARATUS AND METHODOLOGY

MATERIALS:

Toyoura sand is fine-grained, uniformly graded sand, originated from Toyoura Beach area of Yamaguchi prefecture, Japan. It is standard sand for testing as a laboratory material in Japan and well accepted all over the world. The photograph and grain size distribution curve is shown in Figure 1. Kaolin (hydrated aluminum silicate, $Al_2Si_2O_5(OH)_4$) is soft white clay that is an essential ingredient used in a wide variety of industries. In its natural state kaolin is a white, soft powder consisting principally of the mineral kaolinite, which, under the electron microscope, is seen to consist of roughly hexagonal, platy crystals ranging in size from about 0.1 micrometer to 10 micrometers or even larger. Commercially available non-plastic silt (brand name: DL) was used in this study. The properties of Toyoura sand and fines are presented in Table 1



Toyoura sand

Figure 1. Toyoura sand and its gradation curve

Table1. Physical and mechanical properties of tested materials

Properties of Toyoura sand		Properties of Kaolin clay		Properties of Non plastic silt	
Specific gravity, G_s	2.62	Specific gravity, G_s	2.731	Specific gravity, G_s	2.665
Maximum void ratio, e_{max}	0.946	Liquid Limit, LL	45.1%		
Minimum void ratio, e_{min}	0.637	Plastic Limit, PL	31%		
Mean Diameter, D_{50} (mm)	0.19	Plasticity index, PI	13.5%		

APPARATUS AND SENSORS:

Small size, gear driven and strain controlled triaxial apparatus, as shown in Figure 2 was used for performing experiments. The axial loading system consists of an AC servomotor and a reduction gear system, electro-magnetic clutches and brakes. Stress and strain are precisely controlled by high speed computer. As shown in Figure 3, the specimen and other accessories were set up. Local Deformation Transducer (LDT) invented by Goto (1991) was employed for axial deformation of the specimen. A pair of LDT was attached on surface of the specimen. The photograph of LDT is shown in Figure 4. Clip gauge, as shown in Figure 5, was used for radial deformation (strain) measurement. Three clip gauges were fixed on the specimen. Disk transducer enabling to measure both compression and shear waves (P and S waves) was used. A pair of disk transducer, one in top cap and next in pedestal, was encapsulated in the triaxial apparatus.

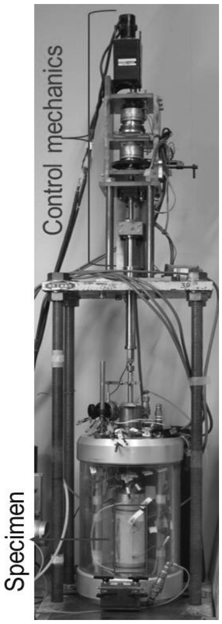


Figure 2. Triaxial apparatus

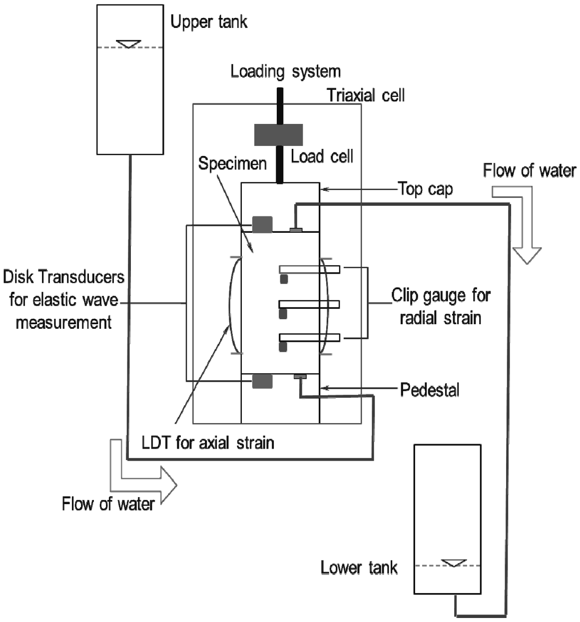


Figure 3. layout of sensors and transducers

METHODOLOGY:

Specimen preparation

Toyoura sand and fines were mixed at dry state by weight proportion. At first, it was stirred manually well. Then the mixed materials were stirred by mechanized stirrer with adding water a little and stirred well for sufficient time to make homogeneously mixed soil. In this study, initial water content was found approximately 0.02-0.04. Then after this, the mixed soil was packed on air tied plastic bags and left for more than one day for eventually distribution of moisture throughout whole soil. The specimen of dimension 75mm diameter and 150mm height was prepared by tamping method. The total soil was divided in 15 parts and each part is compacted within 10 mm. The details of the specimen preparation processes are shown in Figure 7. In this way, the density of specimen was controlled and tried to make homogeneous. The tests were successively performed after collapse behavior tests. So, the specimen prepared as prior described was used for both collapse behavior tests and this study.

Testing procedure

The specimen was prepared at Isotropic stress state of 25Kpa. Then the stress level was raised to 50 kPa and performed collapse behavior evaluation at this stress state as shown in Figure 8. Then, the stress level was upgraded monotonically till 50 kPa at first and the creep stage was maintained for a while (10 minutes) to dissipate the stress thoroughly. Then 11 cyclic loadings with peak to peak stress amplitude of 2 kPa were applied in vertical direction. The strain rate of cyclic loadings was maintained at 0.023mm/min. Again creep stage for elastic wave measurements was maintained. These procedures were repeated on each isotropic stress state of 50, 100, 200 and 400 kPa.

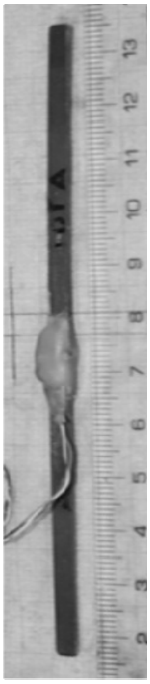


Figure 4. LDT

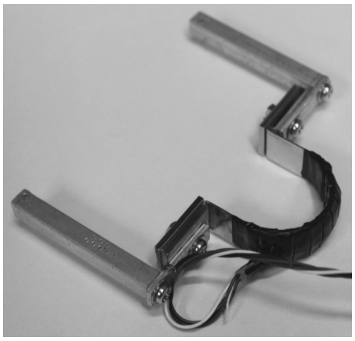


Figure 5. Clip gauge

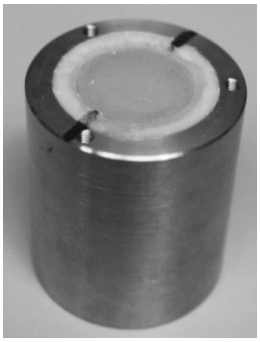


Figure 6. Disk Transducer

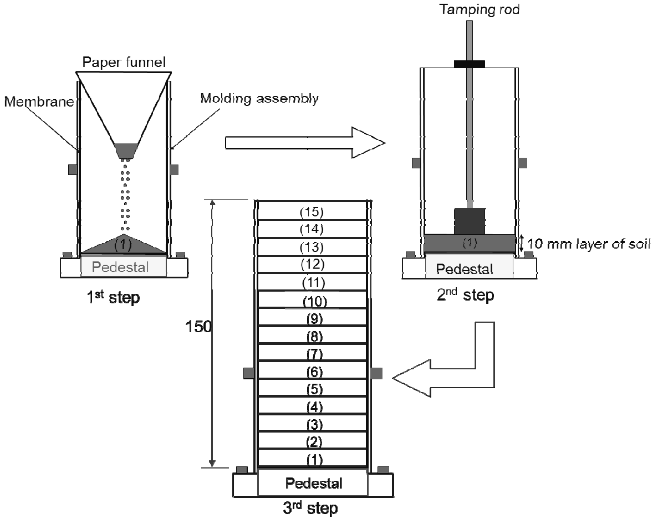


Figure7. Specimen Preparation steps

Poisson's ratio evaluation

Poisson's ratio (ν) reflects the lateral deformational characteristics. Statically it is evaluated as the ratio of lateral (radial) and longitudinal (axial) deformation as given in Eq.1

$$\nu = -\frac{\delta\varepsilon_r}{\delta\varepsilon_a} \tag{1}$$

Where, $\delta\varepsilon_a$ and $\delta\varepsilon_r$ are axial and radial strain variations, which were precisely monitored using the LDT and Clip gauge.

Both compression and shear wave measurements in single specimen allow analyzing the Poisson's ratio of materials dynamically. The velocities of the propagated waves are calculated as;

$$V_p / V_s = \frac{h}{t} \tag{2}$$

Where, V_p and Vs are compression and shear wave velocities, h is the height of specimen and t is the respective time required propagating within specimen during compression and shear wave excitation. The Poisson's ratio in terms of wave velocity is determined as;

$$\nu = \frac{(0.5V_p^2 - V_s^2)}{V_p^2 - V_s^2} \tag{3}$$

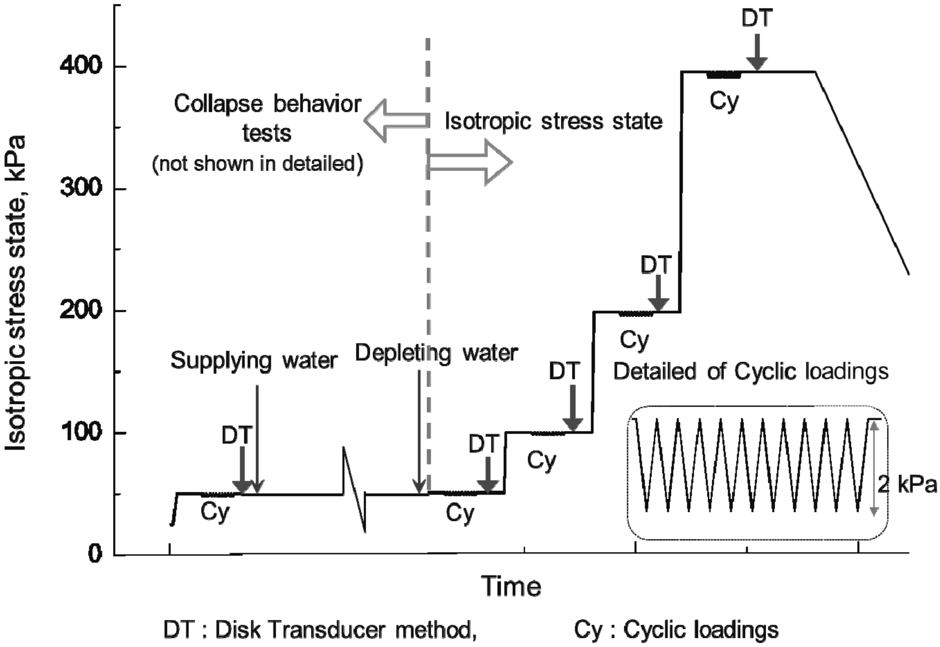


Figure8. Test schemes

TEST RESULTS AND DISCUSSIONS

TEST CASES AND CONDITIONS:

The results of the 16 tests are included here. The lists of experiments including detailed description are shown in Table 2. 7 specimens of kaolin contents Toyoura sand, 6 specimens of non-plastic silt contents Toyoura sand and 3 specimens of sole Toyoura sand were investigated. The specific gravity (G) of the fine content specimen was evaluated by weighted average basis and e_{max} and e_{min} were determined as following Hirama et al.1981. The tests were continued after collapse behavior study on fine content specimens so moisture are still remaining inside the specimens after depleting water in previous stage (collapse behavior tests). The degree of saturation at the beginning of each tests are also mentioned in Table 2.

Table2. List of experiments

Test no.	Type of fines	Percentage of Fine (%)	Initial relative density (%)	Initial dry unit weight (gm/cm^3)	Specific gravity (G)	Initial degree of saturation (%)
1	kaolin	5	52	1.415	2.627	28
2	kaolin	5	42	1.378	2.627	20
3	kaolin	5	63	1.45	2.627	33
4	kaolin	5	71	1.482	2.627	26
5	kaolin	10	79	1.472	2.632	65
6	kaolin	10	89	1.516	2.632	28
7	kaolin	10	64	1.338	2.632	26
8	Non-plastic silt	10	68	1.422	2.625	57
9	Non-plastic silt	10	62	1.401	2.625	58
10	Non-plastic silt	10	73	1.441	2.625	45
11	Non-plastic silt	15	84	1.451	2.628	46
12	Non-plastic silt	15	76	1.413	2.628	43
13	Non-plastic silt	15	86	1.463	2.628	55
14	-	-	78	1.527	2.621	0
15	-	-	99	1.599	2.621	0
16	-	-	68	1.498	2.621	0

STATIC EVALUATION OF POISON'S RATIO:

Poisson's ratios are statically evaluated based on the strain variation obtained during cyclic loadings. As shown in Figure 8, cyclic loadings are applied in each isotropic stress states (50, 100, 200 and 400 kPa) and the strains variations were being monitored by LDTs and clip gauges for whole experiment. The typical axial and radial strain variation obtained on kaolin content Toyoura sand at isotropic stress state of 100 kPa are shown in Figure 9. Axial strain variations are plotted on upper part by square symbols and radial strain variations are plotted on lower part by circle symbols in this plot. The axial and radial strain variations are plotted in this plot is derived by averaging the results of pair of LDTs and three numbers of clip gauges. Similar to this, the axial and radial strains variations achieved on non-plastic silt content Toyoura sand at 100 kPa is shown in Figure 10 and Figure 11 is obtained on pure Toyoura sand specimen at 400 kPa. Those strains variations are observed due to applying cyclic loadings of 2 kPa peak to peak stress amplitude. The resulted strain variations are found varied for several cases such as; the axial strains in Figure 9 and 10 are found to be nearly 0.0015% where in case of pure Toyoura sand, it is found to be 0.001% and corresponding radial strains are also found to be varied. While evaluating the Poisson's ratio value, only axial strain variation by 0.001% and corresponding radial strain variations are utilized. The typical radial strain versus axial strain obtained on non-plastic silt content Toyoura sand is shown in Figure 12. This plot is derived by the data of 10th cycle. Fitting linear curve, the slope, Poisson's ratio in here, is evaluated. Similarly, the radial strain versus axial strain and corresponding Poisson's ratio value obtained on pure Toyoura sand is shown in Figure 13. 11 cyclic loadings were actuated in each stress state, representing strains behaviors during cyclic loadings, the data of 5th and 10th cycles are analyzed for fine content Toyoura sand. Data of each cycle were analyzed in case of Toyoura sand specimens.

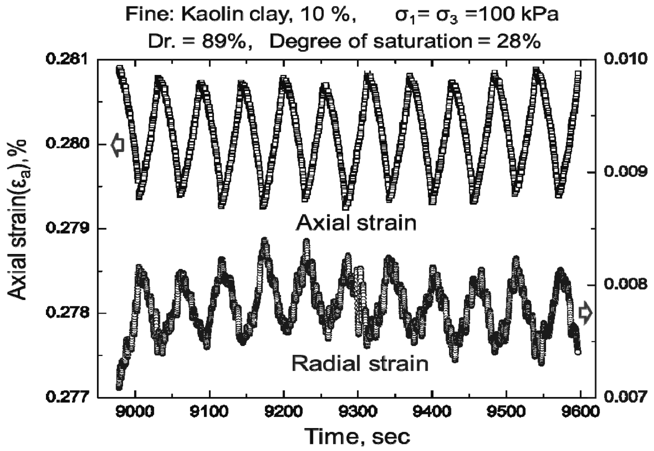


Figure9. Axial and radial strain variations obtained on kaolin content Toyoura sand

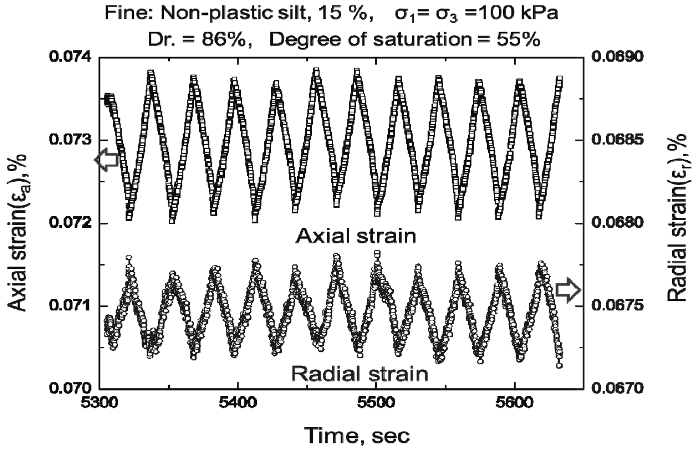


Figure10. Axial and radial strain variations obtained on non-plastic silt content Toyoura sand

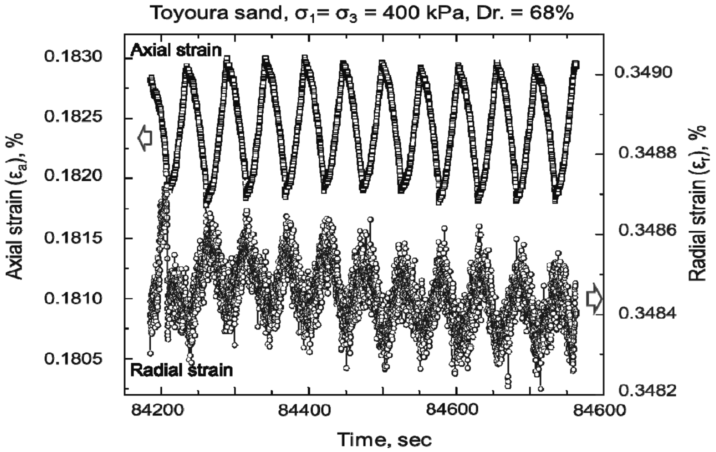


Figure11. Axial and radial strain variations obtained on Toyoura sand

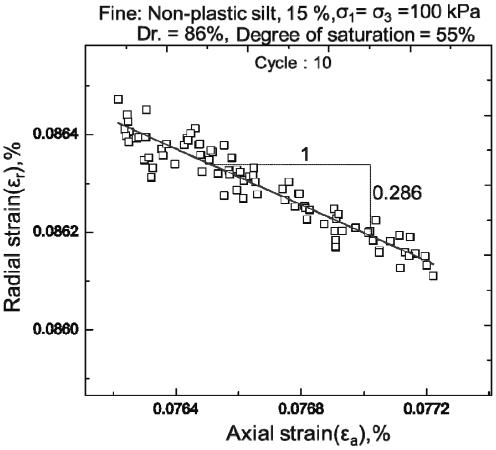


Figure12. Typical Plot of radial versus axial strains obtained on non-plastic silt content Toyoura sand

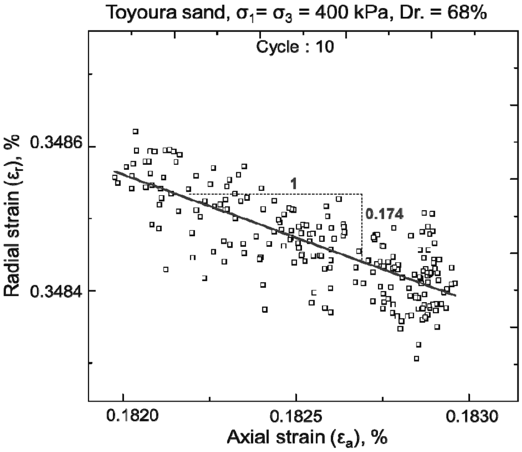


Figure13. Typical Plot of radial versus axial strains obtained on Toyoura sand

DYNAMIC EVALUATION OF POISON'S RATIO:

The success of the measurement of both compression and shear waves on a single specimen at same stress states makes possible to evaluate the Poisson's ratio in terms of compression and shear wave velocities which is called as dynamically evaluation of Poisson's ratio. Disk Transducer method, recently developed method enabling to measure both compression and shear waves in a single specimen, and is adopted in this study. Input voltage, working frequencies and interpretation techniques are important factors in elastic wave measurement method. The input voltage ranges of 50-100 volts were employed. Previous researcher suggested for using a sinusoidal wave to reduce the uncertainties in the interpretation of the wave (Viggiani et al., 1995). The same shape signals on input and output signal could be achieved using a single sine wave as the input signal. Jovicic proposed the use of a sinusoidal wave and adoption of the point of the first inversion as the arrival of shear wave and suggest employing the high frequency signals for reducing the near field effects (Jovicic et al. 1996). Following the previous researchers, sinusoidal waves are employed in this study. The compression waves are evaluated as the first sense (deflection) of the signal on time domain series is the real arrival of the compression waves. The travel time are dealt considering the time gap between the rising of the input signal to the rising of output signal. Interpretation of the shear waves is not still clear and several opinions are presented by various researchers about interpretation techniques. Previous studies showed that the first deflection of the shear wave signal may not correspond to the arrival of the shear wave. Disturbances and reflected compression wave travels in the speed of compression wave and arrived at first which create ambiguity on determination of the real shear wave arrival. In single sinusoidal excitation, the rising to rising travel time is defined as the distance from the rising of input signal to the first zero crossing point on the time domain series of the output signal following the recommendation by Jovicic (Jovicic et al. 1996) . This zero baseline correction is imposed to minimize the effect of the near field.

Typical plots of input and output signals obtained on 5% kaolin content Toyoura sand are shown in Figure 14 (A: P waveforms and B: S waveforms). Those waveforms are generated exciting single sinusoidal signal of 20 kHz through disk transducer at top cap (transmitter disk transducer). The input and received signals from lower stress state to higher stress states are shown form bottom to top in these plots (Both P and S wave plots). The input signals are traced in volt and and received signals are plotted in millivolt units. The X-axis are representing the times in microsecond. As shown in plots (Figure 14; A and B) the travel times for propagating signals are determined (T_p= Travel time for P waves and T_s = Travel time for S waves). Then, the velocities of signals are found out using Eq. (2), dividing the height of specimen by corresponding travel times for P and S waves in each stress level. The Poisson's ratios are determined computing the wave velocities in Eq. (3). These processes are conducted in each test of non-plastic silt content Toyoura sand and Toyoura sand specimens. The typical signal waveforms obtained on 10 % and 15 % kaolin content Toyoura sands are shown in Figure 15 & 16 (A: P waveforms and B: S waveforms). The meanings of symbols and axes are similar to previous plot (Figure 14). Toyoura sand specimens are tested in dry condition. So the waveforms plotted in Figure 17 are obtained in dry condition. The plots regarding to kaolin content Toyoura sand and non-plastic silt content Toyoura sand are generated using data of exciting 20 kHz single sinusoidal signal as input but in case of Toyoura sand, Figure 17 are generated during exciting 25 kHz single sinusoidal signal as input. 20 kHz frequency was found be relatively easily interpretable as compared to the signals of other frequencies in cases of kaolin content Toyoura sand and non- plastic silt content Toyoura sand. For, Toyoura sand specimen 25 kHz frequency was found to be better than other frequencies. It is experienced by comparing received signals of several inputs of various frequencies as well as FFT (Fast Fourier Transformation) analysis. So, those frequencies are referred for analyzing Poisson's ratio by elastic wave measurement in this study.

DISCUSSION ON RESULTS:

Fine particles in soil play a significant role in mechanical properties and deformation characteristics. Many natural soils might contain the fines. So, investigation of fine contents soils is important. Several sorts of fines alter the soil's properties in different ways. Mainly fines are broadly classified in two groups; silt and clay. Representing those both types, kaolin clay and non- plastic silt are used. Fines are mixed in various proportions and observed results are discussed here. The Poisson's ratios obtained on 5% kaolin content Toyoura sand are shown in Figure 19. The results obtained by both static and Disk Transducer method are included. The Poisson's ratio values are plotted against the isotropic stresses. The open symbols are depicting the results obtained by Disk Transducer method and solid symbols are associated with the results of statically determined by employing small strain cyclic loadings. Results obtained on several specimens have several densities have plotted together in this plot. The reasonable results following the trend of decreasing Poisson's ratio value with increasing isotropic stress states are found by Disk Transducer method where the results by static method are found to be scattered highly. The results obtained on 10 % kaolin contents Toyoura sand are depicted on Figure 20. Results are found to be followed the previous plot. Statically determined Poisson's ratio values are found to be extensively scattered and higher than dynamically determined Poisson's ratio values. Each specimen contained the moisture during the experiment. That might be one reason of having scattered results by static method. The moisture content in the specimens is also mentioned in each plot (Figure 19 to Figure 22). Similarly, the results achieved on non-plastic silt Toyoura sand are shown in Figure 21 and 22. The results obtained on 10% non- plastic silt are plotted in Figure 21. The specimens of similar densities ranges (Dr.: 62% – 73%) with similar degree of saturation are tested. The reasonable results, higher Poisson's ratio value in specimen of lower density, are noticed by Disk Transducer method. The statically determined results are rarely followed this trend. Same as this, the results acquired on 15% non-plastic silt content Toyoura sand are shown in Figure 22. The most results are found to follow same trend as obtained on other tests as prior explained. In addition to this, three tests are conducted on pure Toyoura sand (without any fines) in this study and the achieved outputs are shown in Figure 23. All cases of fine content Toyoura sand with moisture showed the higher Poisson's ratio value by static method as compared the Disk Transducer method. But in case of Toyoura sand in dry condition, the Poisson's ratio value evaluated by applying small strain cyclic loading are found to be lower than those obtained by Disk Transducer method. The results (both obtained by Disk Transducer method and static method) are found to be followed the trend of decreasing Poisson's ratio values with increasing isotropic stress state. Observing the results obtained in all those tests, the Poisson's ratio values derived by Disk Transducer method are found to be reasonable and reliable. The results obtained employing Disk transducer method on those experiments is summarized on Figure 24. The Poisson's ratio values obtained by elastic wave measurement are plotted against the isotropic stress state. The plotted results are belongs to the several experiments with varying fine contents, densities and moisture contents etc. Those parameters might influence the results (Poisson's ratio values). So direct comparison of the results plotted in Figure 24 might not be well appropriate. Even though broadly observed result showed that the higher Poisson's ratio values are resulted in higher fine content Toyoura sand.

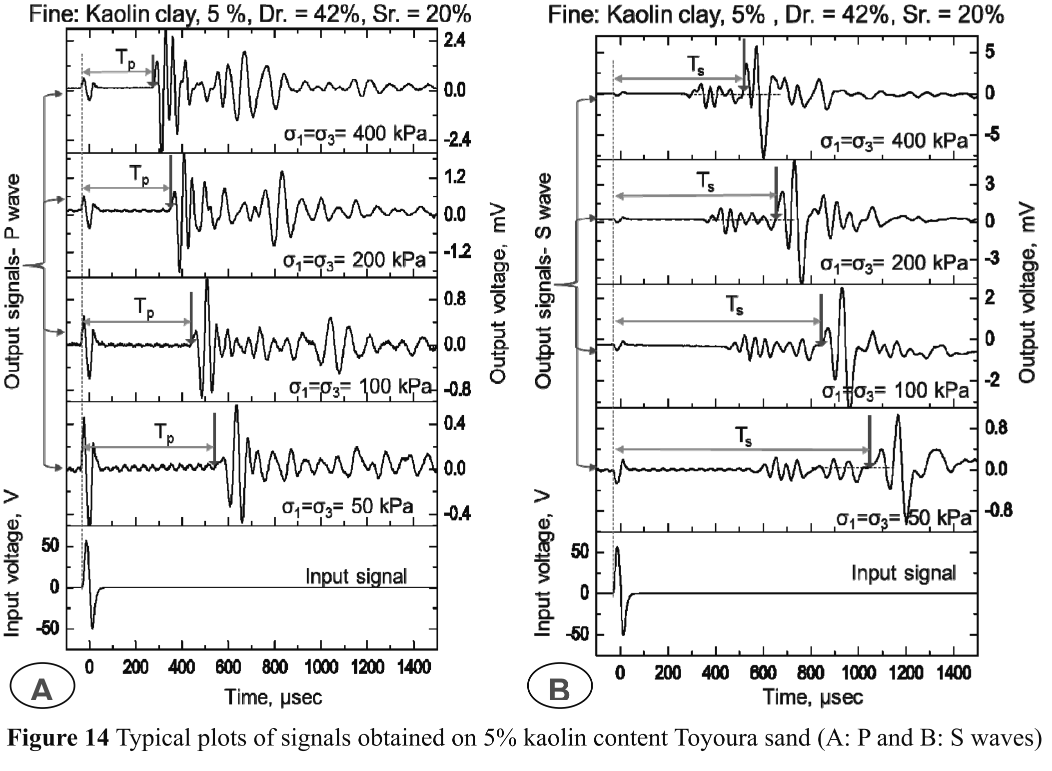


Figure 14 Typical plots of signals obtained on 5% kaolin content Toyoura sand (A: P and B: S waves)

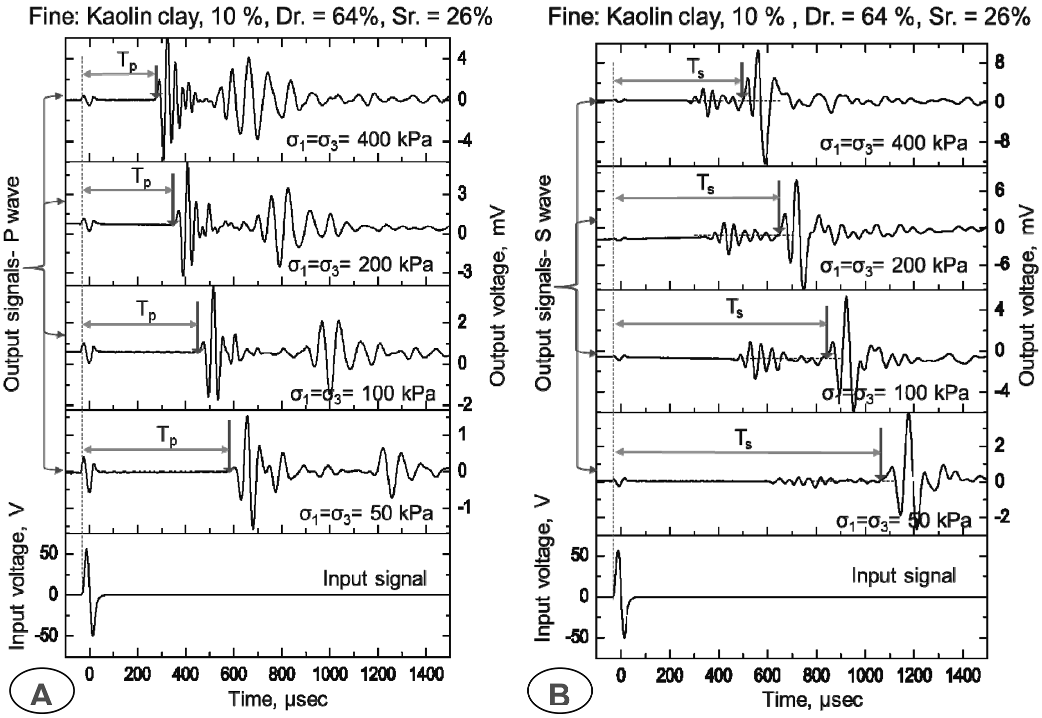


Figure 15. Typical plots of signals obtained on 10% kaolin content Toyoura sand

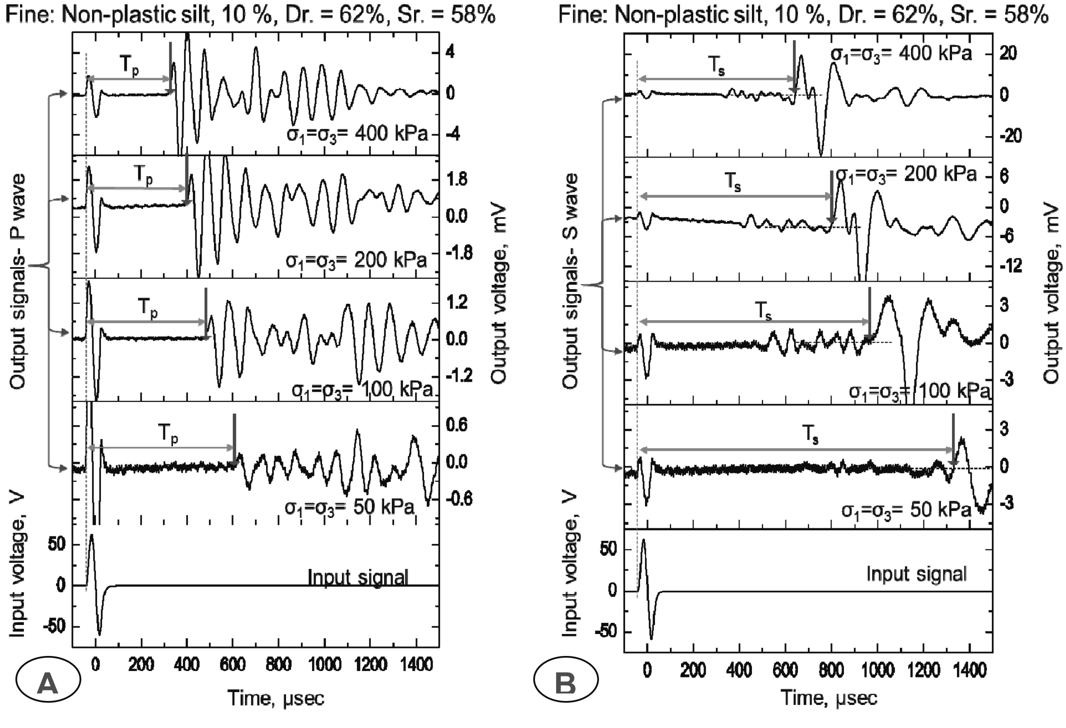


Figure16. Typical plots of signals obtained on 10% non-plastic silt content Toyoura sand

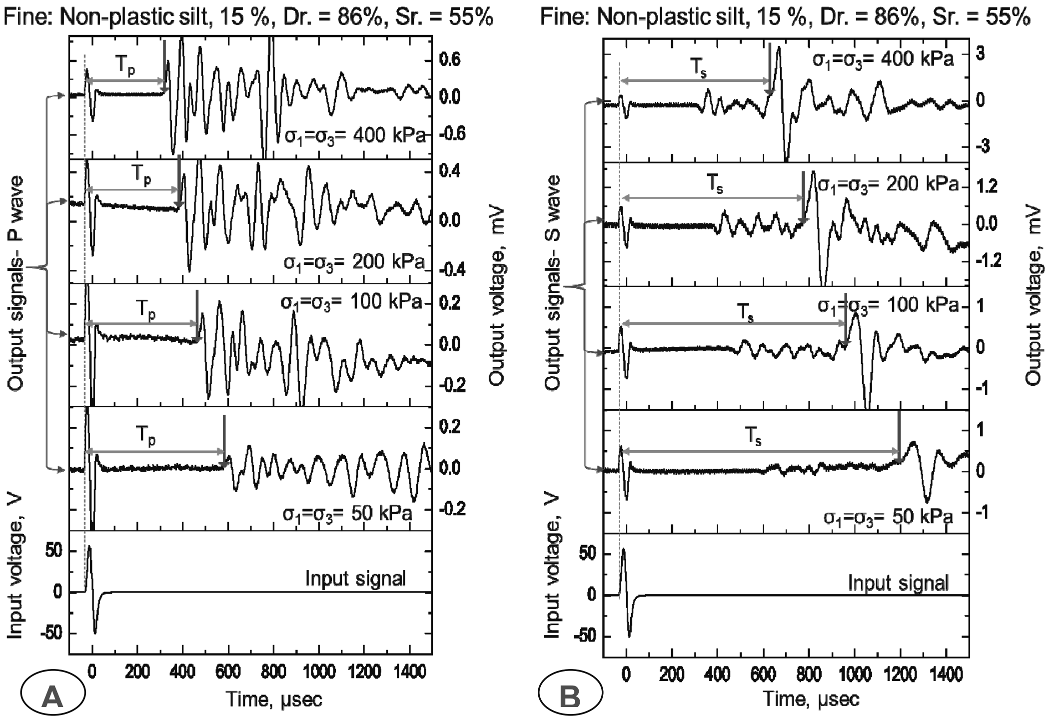


Figure17. Typical plots of signals obtained on 15% non-plastic silt content Toyoura sand

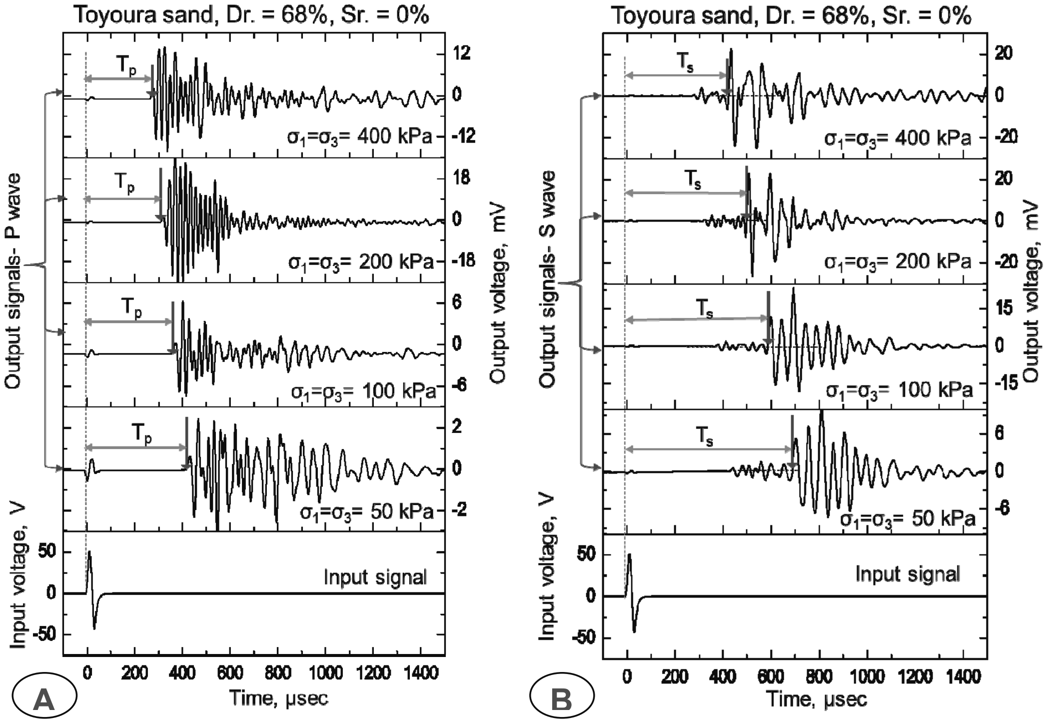


Figure18. Typical plot of signals obtained on Toyoura sand

NORMALIZATION OF OBTAINED RESULTS:

Results are found to be affected by several factors such as degree of saturation, density of specimens, amount of fines etc. To evaluate the effects of fine contents, the results are tried to normalize with respect to degree of saturation. Toyoura sand are tested in dry condition so, the remaining results are converted to equivalent with dry condition. During the collapse behavior analysis, the specimens were subjected from dry to wet conditions at isotropic stress state of 50 kPa, the Poisson's ratio values obtained at various degree of saturation showed the relation of Poisson's ratio values and degree of saturation. The Poisson's ratio values obtained on kaolin content Toyoura sand are plotted in Figure 25. In this plot, the Poisson's ratio values are plotted in Y axis and degree of saturation is plotted in X-axis. The results obtained in kaolin content Toyoura sand ranges fines from 5% to 15 % including Toyoura sand are included. The best fitted linear line are drawn for each category of soils (Toyoura sand, 5% kaolin content Toyoura sand, 10 % kaolin content Toyoura sand and 15 % kaolin content Toyoura sand). The achieved intercept and slope of the fitted line are listed on Figure 25. We have seen that Poisson's ratio values can be expressed in terms of degree of saturation for soils having several degree of saturation. In linear equation, Y represents the Poisson's ratio value and X represents the degree of saturation. So, the degree of saturation can be dealt as a variable. The Poisson's ratio of specimen will be equal to intercept (a) while the degree of saturation tends to zero (dry condition). The slope value (b) reflects the effects of amount of kaolin clay. The values of b for different soils (Pure Toyoura sand to 15 % kaolin content Toyoura sand) are compared and found to be nearly linear relation according to amount of kaolin content. The obtained b values are plotted with respect to amount of kaolin content in Figure 26. The obtained linear relationship is also included in this plot. In summary, it can be written as;

$$\nu = a + b * Sr \tag{4}$$

Where, Sr is degree of saturation in percent.

Slope (b) in Eq. (4) is found to be linear function of type of soil (relate with amount of kaolin in here). Then;

$$b = a_1 + b_1 * amountofkaolin \tag{5}$$

This equation with a_1 and b_1 are depicted in Figure 26.

Substituting the Eq. (5) in Eq. (4), the required Eq. is found.

$$\nu = a + (a_1 + b_1 * amountofkaolin) * Sr \tag{6}$$

Employing Eq. (6), the obtained results at various degree of saturation are normalized to equivalent with dry specimen. The Normalized results derived from the kaolin content Toyoura sand are shown in Figure 29 including other results.

Similar to kaolin content Toyoura sand, non-plastic silt content Toyoura sand's results are dealt similarly. The Poisson's ratio values obtained with several degree of saturation at isotropic stress state of 50 kPa are shown in Figure 27. The best fitted linear curve for each types of soil are also included in this figure. As prior mentioned, the slope of linear curve in this figure (figure 27) can be regarded with the type of soil (amount of non- plastic silt in this context) which is shown plotting the linear line on slope (b) versus amount of non- plastic silt in figure 28. As prior explained, employing Eq. (6), the achieved results by Disk Transducer method at various degree of saturation are normalized to equivalent with dry specimen. The normalized results including all normalized results by disk Transducer method from others tests are shown in Figure 29.

Figure 29 shows Poisson's ratio values obtained on several soil having fines including Toyoura sand with respect to isotropic stress state. The results of all tests in this study are included in this plot. The results clearly showed the influence of fine contents on Poisson's ratio values. The Poisson's ratios of pure Toyoura sand are found to be lowest and the results derived on 15% non-plastic silt content Toyoura sand showed the highest Poisson's ratios. The increasing of the Poisson's ratio values with increasing amount of fines (regardless to type of fines) can be seen in this figure. All the results are found to be followed the trends of decreasing Poisson's ratios with ascending isotropic stress states.

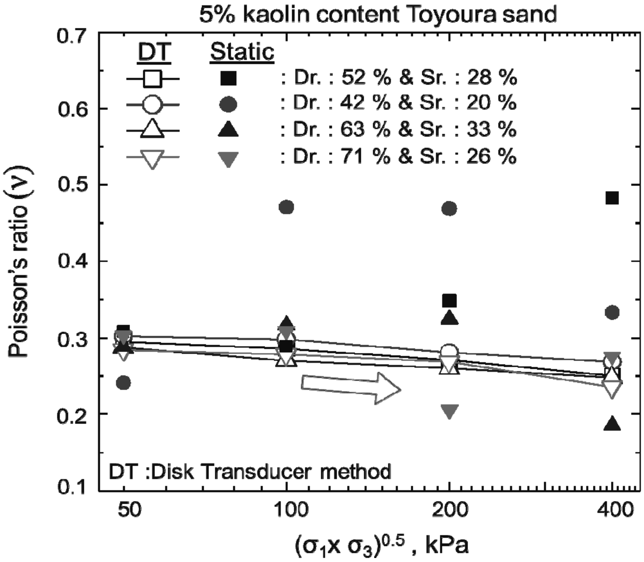


Figure 19. Poisson's ratio obtained on 5 % kaolin content Toyoura sand

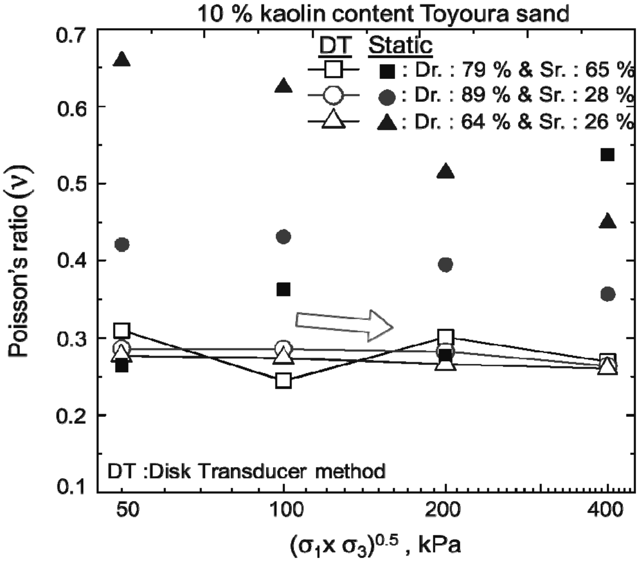


Figure 20. Poisson's ratio obtained on 10 % kaolin content Toyoura sand

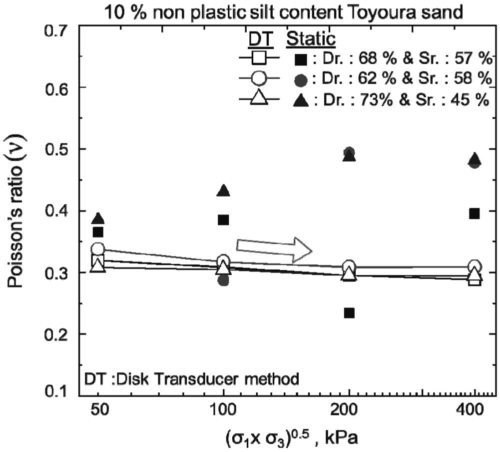


Figure 21. Poisson's ratio obtained on 10 % non-plastic silt content Toyoura sand

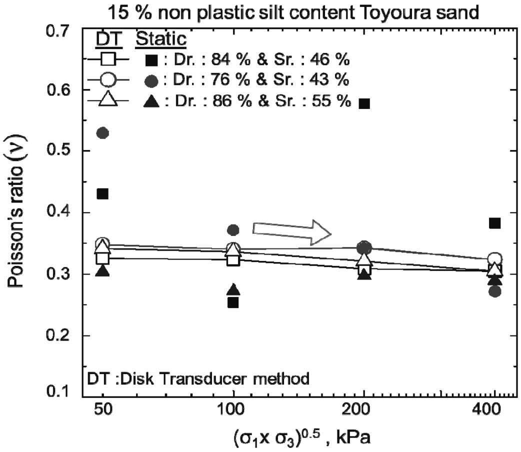


Figure 22. Poisson's ratio obtained on 15 % non-plastic silt content Toyoura sand

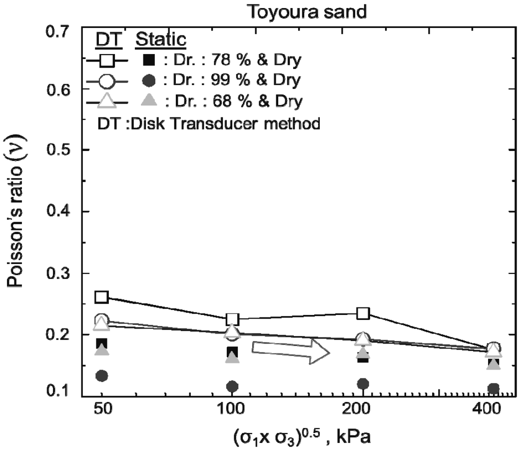


Figure 23. Poisson's ratio obtained on Toyoura sand

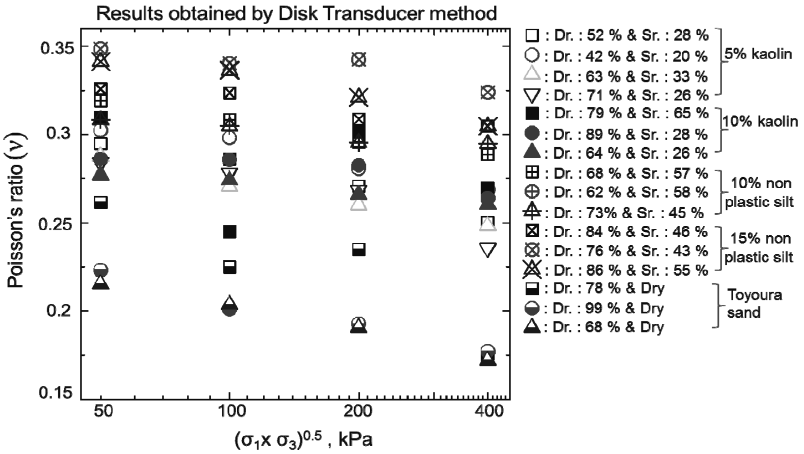


Figure 24. Poisson's ratio obtained by Disk Transducer method on various specimens

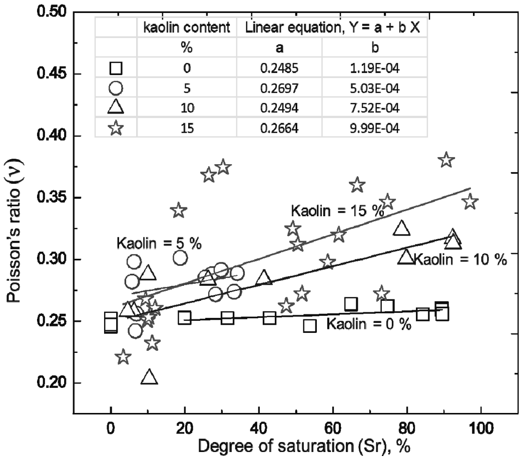


Figure 25. Poisson's ratio obtained on kaolin content Toyoura sand at several degree of saturation

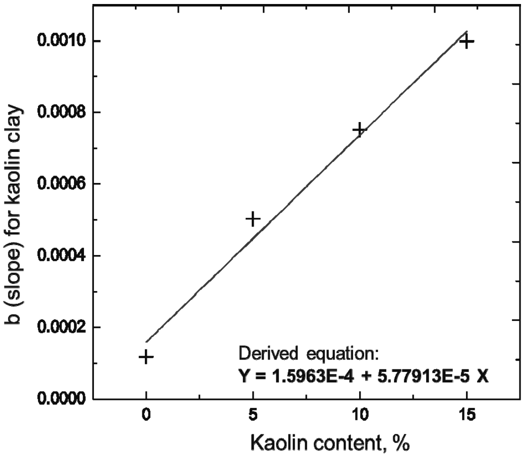


Figure 26. Slope of regression line with respect to kaolin content

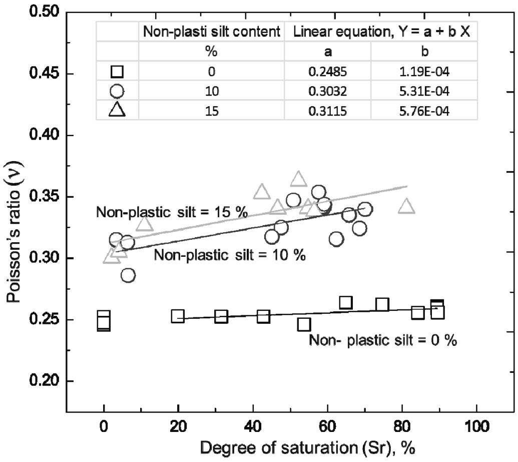


Figure 27. Poisson's ratio obtained on non-plastic silt content Toyoura sand at several degree of saturation

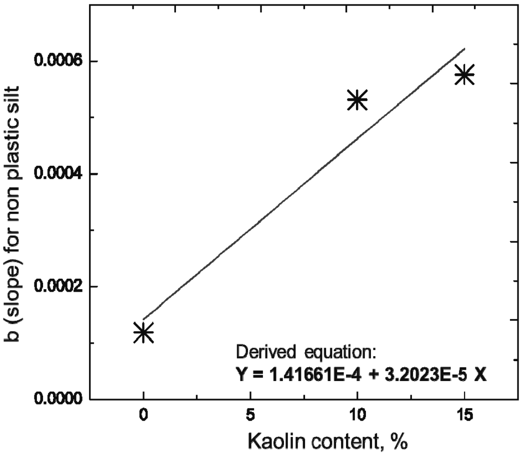


Figure 28. Slope of regression line with respect to non-plastic silt content

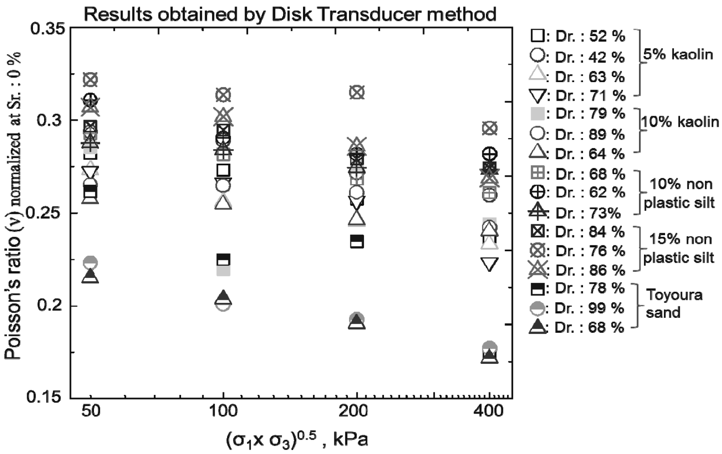


Figure 29. Normalized Poisson's ratio by Disk Transducer method

CONCLUSIONS

Poisson's ratio of clayey and silty sands was investigated on cylindrical triaxial specimens employing small strain cyclic loadings and recently developed Disk Transducer method. Disk Transducer was used to measure both P and S waves simultaneously in those specimens. Based on the achieved results, the following conclusions are drawn:

- The Poisson's ratio of kaolin clay and non-plastic silt contents Toyoura sand (clayey and silty fine sand) were successfully evaluated by both statically applying small strain cyclic loadings and dynamically employing Disk Transducer method.
- The Poisson's ratios evaluated measuring both compression and shear waves on a single specimen at the same physical conditions resulted reasonable, reliable and well trended as compared to the results obtained by static measurement on same specimens.
- Poisson's ratios of the fine content specimens having certain level of moisture content are evaluated. It means all fine content soil specimens are tested in partially saturated condition. Disk Transducer method for elastic wave measurement on laboratory specimen showed the good performance in cases of partially saturated conditions also. The scope of Disk Transducer method is extended.
- Statically evaluated Poisson's ratio values on those specimens are found to have higher degree of scattering and higher values (except Toyoura sand) as compared to the results obtained measuring compression and shear wave velocities by means of Disk Transducer.
- Poisson's ratio values were found to be influenced by amount of fines in sand. The higher amount of fines tended higher Poisson's ratio values.

REFERENCES

1. Brignoli, E. G. M., and Stokoe, K. H., II, 1996, "Measurement of shear waves in Laboratory Specimens by Means of Piezoelectric Transducers", *Geotechnical Testing Journal*, Vol. 19, No.4, December, pp. 384-397
2. Burland, J.B and Symes, M., 1982, "A simple axial displacement gauge for use in triaxial apparatus", *Geotechnique,* 32(1), 62-65.
3. Goto, S., Tatsuaka, F., Shibuya, S., Kim, Y-S., and Sato, T. (1991)," A simple Gauge for local small strain Measurements in the laboratory", *Soils and Foundations*, Vol.31, No.1, pp.169-180.
4. Hirama, K (1981). Consideration on significance of relative density, Proc. Symposium on relative density of sand and engineering properties, Japanese Geotechnical Society, Japan: 53-56
5. Jovicic, V., Coop, M. R., and Simic, M., 1996, "Objective Criteria for Determining Gmax from Bender Element Tests", Technical Note, *Geotechnique*, Vol. 46, No. 22, pp. 357-362.
6. Kumar, J. and Madhusudhan, B.N. (2010), "Effects of relative density and confining pressure on Poisson ratio from bender and extender elements tests", *Geotechnique* 60, No.7, 561-567
7. Lee, C., Truong, Q.H. and Lee, J. S., 2010, "Cementation and bond degradation of rubber-sand mixtures", *Canadian Geotechnical Journal*, Vol. 47, pp. 763-774.
8. Lo Presti, D.,Pallara, O.,Lancelotta, R.,Amandi, M. and Maniscalco,R.,1993 "Monotonic and cyclic loading behavior of two sands at small strains", *Geotechnical Testing journal*, Vol.16, No. 4 pp.409-424.
9. Suwal, L. P., and Kuwano, R., 2010 "Development of disc shaped pieze-ceramic plate transducer for elastic wave measurements in laboratory specimens", *Seisan-Kenkyu*, Bimonthly Journal of Institute of Industrial Science, The University of Tokyo, Vol.61,No.6, pp. 123-128
10. Tatsuoka, F., and Shibuya, S., 1992, "Deformation Characteristics of Soils and Rocks from Field and Laboratory Tests", *Proceedings of 9th Asian Regional Conference of SMFE*, Bangkok, Vol.2, pp. 101-170.
11. Tatsuoka, F and Kohata, Y (1995) "stiffness of Hard soils and soft rocks in Engineering applications", *keynote Lecture, Proceedings of International Symposium Pre-failure Deformation of Geomaterials* (Shibuya et al., eds), Balkema, 2,pp. 947-1063
12. Viggiani, G. and Atkinson, J. H., 1995, "Interpretation of Bender Element Tests", *Geotechnique*, Vol. 45, No. 1. pp. 149-154.