# Dynamic characters of Nanjing sand,GuanZhou sand ,Harbin sand and Lanzhou sand compared with Fujian sand[1]

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**ABSTRACT :**

Nanjing sand,Guangzhou sand, Nanzhou and Yincuan sand ,Harbin sand are studied on minerals composition, grain style and dynamic shear characters by shake table tests and dynamic tri axial tests. Compared with round sand , dynamic shear mould and extra-pore-pressure of different structural sands, such as schistose,staff grain sand and other non-regular grain sand, are analyzed. The critical shear strain to induce extra-pore-pressure is suggested as a important and effective variable to study structural sands, Referring the dynamic shear dilatancy deformation model of round grain sand, some coefficients of time-dimension-discrete sand dynamic dilatancy model and parameters of elastic-plastic deformation constitutive model are suggested to think of sand structural characters. A simplified dynamic shear deformation equation for typical structural sand is suggested to analyze earthquake engineering problems.

**KEYWORDS:** Schistose and shaft grain sand, dynamic shear deformation, seismic liquefaction

## 1. Introduction

Different geologic strata formation and different rock composition will bring up some typical structure sand, such as round-grain sand and slice sand and pole sand ,some sands distribute in regular arrange along the ocean circulation or agree with the coast line. In general ,round grain sand is regarded as standard sand in some countries, such as Monterey sand , Fujian sand, Niigata sand, Otwa sand, the main part of those sands are round-grain-quartz sands, but,the mica content and distribution and orientation vary in the natural sands,the fabric of micaceous sand has a major influence on its mechanic behaviors including it's easily collapsed under particular shearing direction loading. some of these features in the artificial micaceous sand with 2.5% mica are illustrated by tests. More researches show that mechanical characters are different among those sands, the dynamic characters of slices sand are very complex compared with round sand, porosity of Nanjing sand is bigger than Fujian sand(Chen 2002), average grain size of Fujian sand is smaller, and density of sand is big, the asymmetry coefficients is big, slice sands and pole sands exist in YeziTer river and Zhujiang river ,where mass contain percent of slice and pole grains sand is more than 20%, and shear modulus is bigger 30 % ,damp ratio is less than Fujian sand, mineralogy composition of two sand are different, and particle sizes is different because that there are many quartz and many hydroxide sheet ,other muscovite schematic diagram and slit miner and change proceed brings , the quartz content is near to 50 %~60%. Many recordings show that sands dynamic characters are obviously effected by sands structural properties duringearthquake, Tanshan earthquake in 1976（*Liu ying* 1991）, through the sand sort and conditions of embedding is same, but the seismic liquefaction disaster is different, some place had broken serious seismic liquefaction, liquefaction in the nearby zone is not heavy, but N of SPT is same, lab researches shown that the sand structure characters in the two place is different. The dynamic shear characters of sand in engineering are very complex , during earthquake and seismic

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liquefaction,sand will produced plastic deformation under dynamic shear loading, the unresvised deformation will affected pore-water pressure development. Theory for studying round particle sand seismic liquefaction is unfit for slice sand and pole sand. Few studies have taken account of affect to the dynamic shear volume because of sand structural characters, in this paper composition and special structure between Nanjing sand ,Guanzhou sand and Harbin's sand are compared with Fujian sand, there is no researches on slice and pole sand structural dynamic characters.

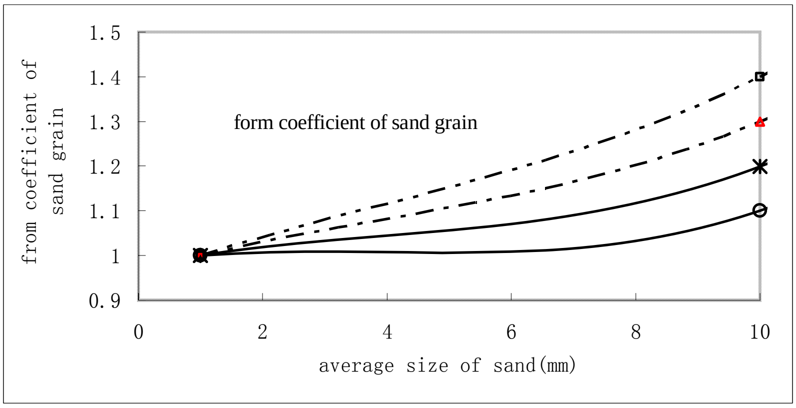
Table 1 the main composition of some typical sands

| composition | Fujian's sand | Monterey sand | Nanjing'sand (YeziTer river's sand ) | Guangzhou's sand （Zhujiang river's sand ） | Harbin's sand Songhuariver's sand | Yinquan's sand |
|---|---|---|---|---|---|---|
| quartz | 50-70% | 50-70% | 30% | 30% | 30% | 50-70% |
| mica | 30% | 30% | 40% | 40-50% | <30% | <30% |
| chlorite | <5% | 5-10% | 30% | <3% | <10% | <10% |
| Other mineral | <5% | 5-10% | <1% | | <5% | <5% |
| Coefficient of asymmetry | 1.3-1.5 | 1.3-1.6 | 2.0-2.5 | 1.9-2.3 | 1.7-2.1 | 1.5 |
| sand grain shape | Round grain | Round grain | Slice, | Round grain, Slice, pole | Round grain, Slice, pole(very little) | Round grain |

Form coefficient

$$\varsigma = \frac{L}{d} \tag{1.1}$$

L : the distance of long axe direction of sand grain ,
d the distance of short axe direction
D : the average radius of sand grain




□ Nanjing'sand △ Guangzhou's sand ＊Nanzhou'ssand ○ harbin's sand

Figure 1 Form coefficient of several type sand

## 2 Dynamic characters of slice , pole and rounded grain sand

The dynamic modulus and damp ratio of soil sktelton change with different structural sand during the sand dynamic deformation process, damp ratio of rounded sand is smaller than that of slice sand's and pole sand's, the damp of slice pole is the biggest,so Nanjing's slice sand will produce more deformation than round particle sand, Compared with Fujiang's sand, slice grain Nanjing's sand have those dynamic characters: shear modulus of Nanjing's sand is less than that of Fujian's sand in the same relative density and under same conf-pressure , the damp of middle density Nanjing's sand is bigger than that of Fujian's sand as loading in the same conditions, it is very obvious that slice and pole sands have characters that mechanics change in each direction, for example, strength in the horizon direction is smaller than that of upright direction. As earthquake or dynamic loading, the slice and pole sands are easily crashed, which will induce large plastic deformation because there are many grain slips and skleton bend , the serious deformation is broken up, touch part deformation is connect with the from of grain and the contain of slice and pole sand grain,because the touch chance and touch area of different sand are different with rounded sand ,slice and pole, the destroy type is different at touch part, some sands will be crushed, some grain sands will be snap , bend or slip.

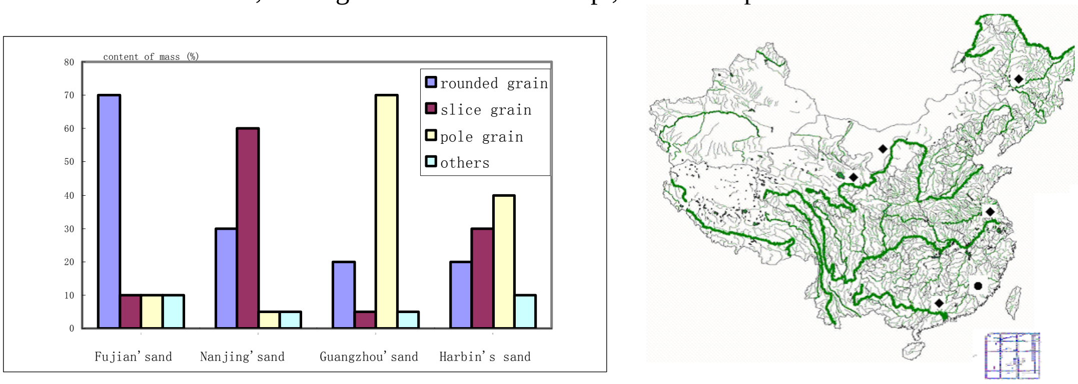



Figure 2 Contain of rounded ,slice and pole grain sand

Table 2 type sand dynamic characters

| | dynamic firm | Asymmetry of strengthen | strengthen ratio | Shear dilitancy | capacity of resist liquefaction |
|---|---|---|---|---|---|
| Fujiang'sand | small | no | >2.5 | <0.1% | high |
| Monterey No 0 sand | small | no | >2.3 | <0.11% | high |
| Niigata'sand | Relatively big | no | <1.7 | 0.15% | low |
| Guangzhou'sand | big | some | <2 | 0.15-02% | common |
| Nanjing's sand | big | obvious | 2.1 | >0.25% | low |
| Harbin's sand | Relatively big | Very little | 1.7-2.0 | 0.22-0.25% | common |

## 3 Sand structure and critical shear strain to induce extra-porous water pressure

Sand structure always bring deformation different in earthquake, for saturated sand, the Nanjing's sand structure characters is that content of slice quartz sand is big , according to the China- Rule method ,Nanjing'sand was regarded to have a high capability to resist liquefaction by SPT ,lots of tests by dynamic tri axial test or by shake table test, shown that: Nanjing's sand is easily liquefy than Fujian's sand it obviously can not ignore structural sands, the reasons are those: (1) the experienced equation SPT is simplified equation by rounded grain sand (or it is standard sand);(2) sand has it's structure characters in different place, the rivers of China is very developed , like water system of Songhua river, Huanhe river, Yezetz river and Zhujiang river, sand sort and property change in different place. In Nanjing city , the mechanism and feature of seismic liquefaction is rounded grain sand and other form sand ( *chen* 2000). Guanzhou lies in zhujiang delta ,at the end of Zhujiang river , the structural character of Zhujiang sand is very special , the content of hydroxide grain and pole grain is high, especially the white hydroxide is that Zhujian sands have some slice sea shells. Guangzhou subway engineering's sand liquefaction researching (Chen 2000-2004)show that sand liquefaction by dynamic tests are obvious easily liquefaction than that by SPT, subsoil treatment have to improve to resist liquefaction.

Sand dynamic shear dilatancy volume deformation is one complex plastic proceed, the extra-pore-water pressure is the main reason to induce seismic liquefaction. Sand dynamic dilatancy test by MTS (Chen wenhua 2002 ,2004,2005)shows that there is a critical shear strain to produce the extra-pore-water pressure, which is a effective method to judge ,

$$\text{if } \gamma > \gamma_s \text{ then } \sigma_w > 0 \tag{3.1a}$$

$$\text{if } \gamma < \gamma_s \text{ then } \sigma_w = 0 \tag{3.1b}$$

It is show that shear dilatancy of Nanjing's sand is bigger than that of Fujian's sand, By the dynamic tri axial loading cycle force, the critical shear strain of Nanjing's sand is 0.00005 ,Fujiang'sand is 0.00008, Songhuajiang Harbin's sand is 0.00006, it means under small seismic force, Nanjing'sand will easily produe extra-pore water pressure, more detailed test results can been seen in literature [5].

From the tab 3 ,the critical shear strain to induce water pore-pressure from big to small are those Fujian's sand , Monterey NO 0 sand, Songhuajiang Harbin's sand, Zhujiang's Guanzhou sand, Yazte Nanjing's sand, Niigata sand, this conclusion is preliminary and uncompleted, compared studying,summary and lots test must be done in next.

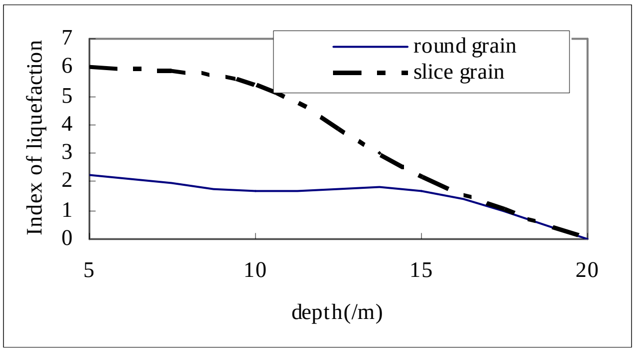



Figure 3 Effect of sand's mic-structure to liquefaction

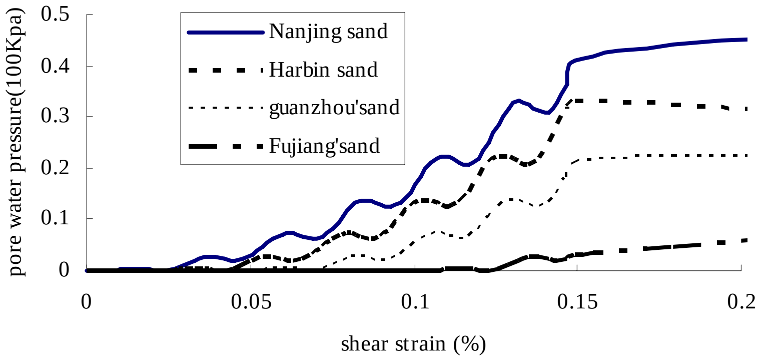



Figure 4 Test of extra-pore-pressure (Dr=40%)

Table 3 Critical shear strain of several sand to produce extra-pore water pressure

| | Fujiang sand | Monterey No 0 sand | Nanjing sand | Guangzhou sand | Harbin sand | Niigata sand |
|---|---|---|---|---|---|---|
| $\gamma_s$ | 0.00008 | 0.00007 | 0.00005 | 0.000055 | 0.00006 | 0.000045 |
| origin | literature[6] | literature[6] | this paper | this paper | this paper | literature[11] |

$\gamma_s$ :critical shear strain

## 4 Dynamic shear volume deformation of structural sand

Lots of dry sand dynamic tests under cycle dynamic shear force show that the bend and shape of curve is different, $\varepsilon_v$ is increase with cycle times N if the shear strain is certain, the increase volume strain in each cycle can be written into time domain variable function( *chen* 2003), that simplify model are based on microcosmic mechanism taking account of soil and loading characteristic, parameters physics meaning of model are clear and be easily measured .

The total shear volume deformation can be written as the following equation .

$$\varepsilon_{ad}(t) = a_0\left(1 - e^{-b_0(\gamma - \gamma_s)t}\right) \tag{4.1}$$

$a_0$ is the parameter which is do with the biggest amplitude of shear strain of earthquake force,
b0 is the parameter connected with soil composition and sort.

$\gamma_s$ critical shear strain ,

Pore water pressure test by dynamic tri axial test in same density sand loading same shear strain In order to study structural sands. Conditions and result of tests are list in tab 4 and figure 5,6

According to sand shear dilitancy theory and sand seismic liquefaction, the pore water pressure model is[3, 10, 11]

$$\Delta\sigma_w = E_r \Delta\varepsilon_{ad} \qquad \Delta\varepsilon_{ad} = \frac{\Delta\sigma_w}{E_r} \tag{4.2}$$

$E_r$ can be calculated as the following steps:

（1） Lab test：

$$E_r = \frac{(\sigma_v)^{1-m}}{mk_2(\sigma_{v,0})^{n-m}} \tag{4.3}$$

m,n,$k_2$ are parameters of test.

（2） also

$$G_d = \frac{E_r}{2(1+u_d)} \tag{4.4}$$

（3） if : $u_d$ =constant ,so that,

$$\frac{E_{r,Nanjing}}{E_{r,Fujiang}} \cong \frac{G_{d,Nanjing}}{G_{d,Fujiang}} \qquad \frac{E_{r,Guangzhou}}{E_{r,Fujiang}} \cong \frac{G_{d,Guangzhou}}{G_{d,Fujiang}} \qquad \frac{E_{r,Harbin}}{E_{r,Fujiang}} \cong \frac{G_{d,Harbin}}{G_{d,Fujiang}} \tag{4.5}$$

（4） Relationship of $E_r$ of different sand in same density (dr=50%)loading same seismic wave.

$$\frac{\Delta\varepsilon_{ad,Nanjing}}{\Delta\varepsilon_{ad,Fujiang}} = \frac{\dfrac{\Delta\sigma_{w,Nanjing}}{E_{r,Nanjing}}}{\dfrac{\Delta\sigma_{w,Fujiang}}{E_{r,Fujiang}}} = \frac{\Delta\sigma_{w,Nanjing}}{\Delta\sigma_{w,Fujiang}} \times \frac{E_{r,Fujiang}}{E_{r,Nanjing}} \approx \frac{\Delta\sigma_{w,Nanjing}}{\Delta\sigma_{w,Fujiang}} \times \frac{G_{d,Fujiang}}{G_{d,Nanjing}}$$

$$\frac{\Delta\varepsilon_{ad,Guangzhou}}{\Delta\varepsilon_{ad,Fujiang}} \approx \frac{\Delta\sigma_{w,Guangzhou}}{\Delta\sigma_{w,Fujiang}} \times \frac{G_{d,Fujiang}}{G_{d,Guangzhou}}$$

$$\frac{\Delta\varepsilon_{ad,Harbin}}{\Delta\varepsilon_{ad,Fujiang}} \approx \frac{\Delta\sigma_{w,Harbin}}{\Delta\sigma_{w,Fujiang}} \times \frac{G_{d,Fujiang}}{G_{d,Harbin}} \tag{4.6}$$

$\frac{\Delta\sigma_{w,Nanjing}}{\Delta\sigma_{w,Fujiang}}$ , $\frac{\Delta\sigma_{w,Guangzhou}}{\Delta\sigma_{w,Fujiang}}$ , $\frac{\Delta\sigma_{w,Harbin}}{\Delta\sigma_{w,Fujiang}}$ were test at same density sand , some parameters can be founded in table 4, or also can be referred by Figure 4,

$\frac{G_{d,Fujiang}}{G_{d,Nanjing}}$ , $\frac{G_{d,Fujiang}}{G_{d,Guangzhou}}$ , $\frac{G_{d,Fujiang}}{G_{d,Harbin}}$ can be measured by Figure 6.

and

$$\frac{\Delta\varepsilon_{ad,Nanjing}}{\Delta\varepsilon_{ad,Fujiang}} \approx \frac{\partial\varepsilon_{ad,Nanjing}}{\partial\varepsilon_{ad,Fujiang}} \tag{4.7}$$

equation(2) also can be written into $\varepsilon_{ad}(t) = a\left(1-e^{-bt}\right)$

so

$$\frac{\varepsilon_{ad,Nanjing}}{\varepsilon_{ad,Fujian}} = \frac{[a_1(1-e^{-b_1 t})]}{[a_0(1-e^{-b_0 t})]} = \frac{a_1}{a_0} \times \frac{(1-e^{-b_1 t})}{(1-e^{-b_0 t})} \tag{4.8}$$

$$\ln\left(\frac{\varepsilon_{ad,Nanjing}}{\varepsilon_{ad,Fujiang}}\right)=\ln\left(\frac{[a_1(1-e^{-b_1 t})]}{[a_0(1-e^{-b_0 t})]}\right)=\frac{a_1}{a_0}\ln\left(\frac{(1-e^{-b_1 t})}{(1-e^{-b_0 t})}\right)=\frac{a_1}{a_0}(b_1-b_0)$$

$$\ln\left(\frac{\varepsilon_{ad,Nanjing}}{\varepsilon_{ad,Fujiang}}\right)=\ln\left(\frac{\Delta\sigma_{w,Nanjing}}{\Delta\sigma_{w,Fujiang}}\times\frac{G_{d,Fujiang}}{G_{d,Nanjing}}\right)=\frac{a_1}{a_0}(b_1-b_0) \quad (4.9)$$

Table 4 experiment and conditions of test in lab ( $\gamma$ =0.2% t=10s, loading sine wave）

| | Conditions of test | | saturated sand | dry sand |
|---|---|---|---|---|
| | Relative density | frequency | extra-pore water pressure | volume strain |
| Fujian'sand | 40% | 1Hz | 12Kpa | 0. 002 |
| Guangzhou | 40% | 1Hz | 22Kpa | >0. 002 |
| Nanjing'sand | 40% | 1Hz | 30Kpa | >0. 002 |
| Harbin'sand | 40% | 1Hz | 21Kpa | >0. 002 |

note ： some parameters come from the literature[11、5、10]， more tests need to be done.

So that

$$\frac{a_1}{a_0}(b_1-b_0)=\ln\left(\frac{\Delta\sigma_{w,Nanjing}}{\Delta\sigma_{w,Fujian}}\right)+\ln\left(\frac{G_{d,Fujian}}{G_{d,Nanjing}}\right) \quad (4.10)$$

$$C=X+Y \quad (4.11)$$

$$\ln\left(\frac{G_{d,Fujian}}{G_{dNanjing}}\right)=Y \qquad \ln\left(\frac{\Delta\sigma_{wNanjing}}{\Delta\sigma_{w,Fujian}}\right)=X$$

$$a_1(b_1-b_0)=Ca_0 \quad (4.12)$$

If i=1,2,3 is represent separately as Guangzhou's sand Nanjing's sand and Harbin's sand.,then

$$b_i=\frac{c_i a_0}{a_i}+b_0 \quad (4.13)$$

$C_i$ can be given by tests of $\frac{G_{d,Fujian}}{G_{dNanjing}},\frac{\Delta\sigma_{wNanjing}}{\Delta\sigma_{w,Fujian}}$.

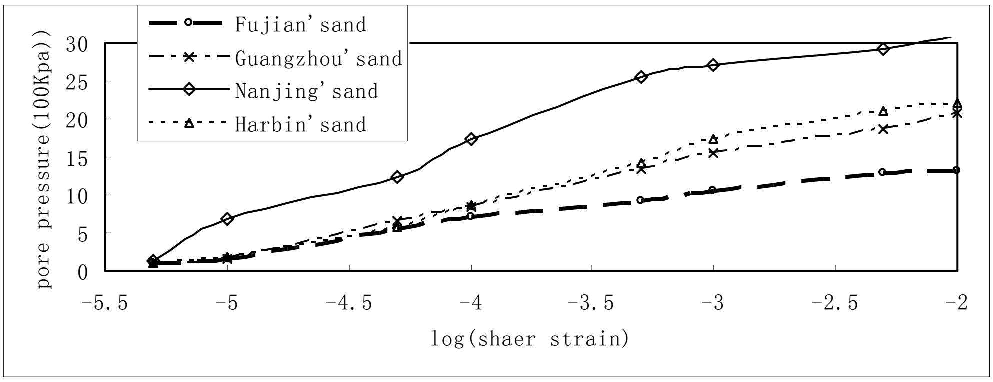



Figure 5 pore -pressure of typed sand in the same test

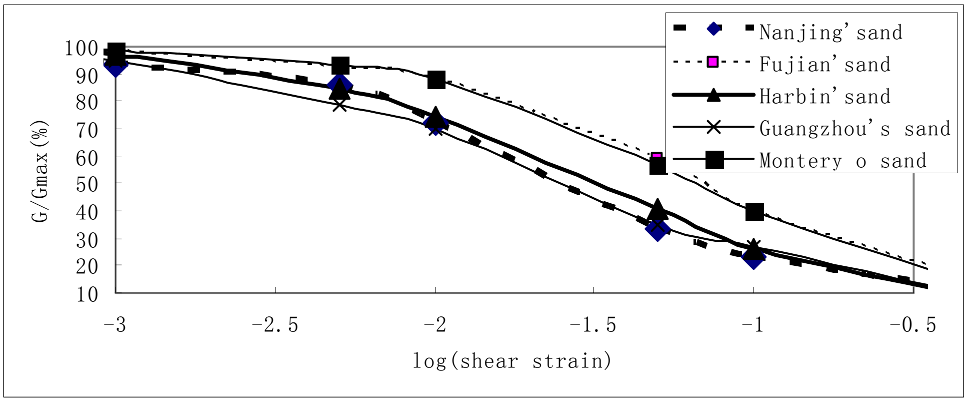



Figure 6 dynamic modulus of typed sand in the same test

Table 5 Parameters of shear dilitancy model think of mic-structure

| | parameters of shear dilitancy | $x(y-b_0)=Ca_0$ | $X_i=\ln\left(\frac{\Delta\sigma_i}{\Delta\sigma_0}\right)$ | $Y_i=\ln\left(\frac{G_i}{G_0}\right)$ | $C_i=X_i+Y_i$ |
|---|---|---|---|---|---|
| Fujian'sand | $a_0$ $b_0$ | | | | |
| Guangzhou'ssand | $a_1$ $b_1$ | $a_1(b_1-b_0)=C_1a_0$ | 0.15 | 0.15 | 0.3 |
| Nanjing's sand | $a_2$ $b_2$ | $a_2(b_2-b_0)=C_2a_0$ | 0.18 | 0.18 | 0.36 |
| Harbin'sand | $a_3$ $b_3$ | $a_3(b_3-b_0)=C_3a_0$ | 0.16 | 0.16 | 0.32 |

**5 conclusion**

(1) Sand structural property is induced by the different structure and mineral composition, and the strata history. (2) Sand mechanics and dynamic characters are all affected by sand structural properties ,(3) compared with rounded grain sand , the proceed of dynamic shear volume deformation of slice and pole grain are very complex, dynamic shear modulus is very different between rounded sand and other fabric sand.(4) , Slice sand or pole sand produce extra-pore water pressure easily under same shear loading and in same density sand.(5 ) the dissociated model of microcosmic volume deformation suggested in this paper can be adjust to analyze different structural sand.

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**References**

G.R.Martin, W.D.Lian and H.B.Seed,(1975). Fundamentals of liquefaction under cyclic loading, *Journal of the Geotechnical engineering*, ASCE, **101:5**, 1--27

Liu ying(1984), Seismic liquefaction of sand(2001)，Eearthquake publish

Zhou Jing (1999) ,Engineering property of Nanjing'sand，Beijing China railway Publishing company。

Chen wenhua(2003), Characters of fabric of Nanjing's sand and evaluation of seismic liquefaction of subsoil of metro of Nanjing, *Rock and soil mechanic* , **10:5 ,** 54-70

Shen zhujiang (1999)，Model to analyze the sand seismic liquefaction，*Geotechonolgy engineering* (Chinese)， **21:1** ,1-9

Cui jie (1998) Affection of deformation of soil skellton to wave propagation of saturated layer，*Earthquake Engineering and engineering Vibration* ， **182:2**，88-92.

Chen wenhua (1999)，Seismic liquefaction of subsoil[D] : Institute of Engineering Mechanics of China Buera Seismic

Chen wenhua(2006), Evaluation of seismic liquefaction of subsoil of metro of Guangzhou，*Civil Engineering* ，8

Locat, J., Tanaka, H., Tan T. S. & Dasari, G.R(. 2002). Natural soils: Geotechnical behavior and geological

knowledge.*Proc. Int. Workshop on Characterisation and Engineering Properties of Natural Soils, Singapore.*
Leroueil, S. & Hight, D.W. (2002). Mechanical behavior and properties of natural soils and soft rocks. *Proc. Int.Workshop on Characterisation and Engineering Properties of Natural Soils,.*
Hight, D. W., Georgiannou, V. N., Martin, P. L..(1999). Flow slides in micaceous sands. *Proc. Of the intenational Symposium on Prolematic Sois, , Japan*. Balkema, Rotterdam, **2**: 945–958.
Sandven, R( 2002). Geotechnical properties of a natural silt deposit obtained from field and laboratory tests. *Proc.Int. Workshop on Characterisation and Engineering Properties of Natural Soils, Singapore.*
Schmertmann, J. H( 1991). The mechanical aging of soils. *J. of Geotech. Engrg*., ASCE, **117:9** 1288–1330.
Schneider, J. A., Laureano, H., Mayne, P. S., Macari, E. J. & Rix, G. J( 1999). Field and Laboratory Measurements of Dynamic Shear Modulus of Piedmont Residual Soils. *Proc. Geo-Congress 99, Behavioural Characteristics of Residual Soils. Geotechnical Special Publication,* 92: 12–25