STUDY OF LOCALIZATION IN SANDY SOIL USING SHEAR WAVE LOGGING

MR. PULPONG PONGVITHAYAPANU

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การศึกษาการวิบัติเฉพาะที่ของดินทรายด้วยคลื่นแรงเฉือน

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต
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พูลพงษ์ พงษ์วิทยภานุ : การศึกษาการวิบัติเฉพาะที่ของดินทรายด้วยคลื่นแรงเฉือน. (STUDY OF LOCALIZATION IN SANDY SOIL BY SHEAR WAVE LOGGING) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร. สุพจน์ เตชวรสินสกุล, 140 หน้า.

การศึกษาการเกิดปรากฏการณ์ Localization ในมวลดินเป็นหัวข้อหนึ่งที่สำคัญในงานวิจัยทางวิศวกรรมปฐพีมากว่า 50 ปี แม้ว่าการศึกษาวิจัยโดยอาศัยทฤษฎีและการจำลองทางคณิตศาสตร์จะสามารถทำให้ทราบถึงพฤติกรรม Localization ได้ดีในระดับหนึ่ง แต่เนื่องจากความไม่ต่อเนื่องของมวลดินภายในบริเวณดังกล่าวนั้นมีความซับซ้อนมาก การศึกษาจากการทดสอบดินในห้องปฏิบัติการจะทำให้รู้ถึงพฤติกรรมของความไม่ต่อเนื่องดังกล่าวได้มากยิ่งขึ้นโดยอาศัยเครื่องมือทดสอบแบบดั้งเดิมและที่พัฒนาใหม่ เช่น การใช้รังสีแกมม่า การใช้ภาพตัดขวางจากรังสีเอ็กซเรย์ และการวิเคราะห์ภาพถ่าย เป็นต้น แต่การทดสอบโดยใช้เครื่องมือดังกล่าว ผู้ทดสอบจำเป็นต้องมีความเชี่ยวชาญและประสบการณ์ด้านเทคนิคในการติดตั้งเครื่องมือ การใช้เครื่องมือ และการวิเคราะห์ผล ซึ่งในปัจจุบันการทดสอบโดยใช้ Bender Element ได้รับความนิยมอย่างแพร่หลายเนื่องจากความง่ายในการทดสอบและราคาไม่แพง การทดสอบโดยใช้ Bender Element นี้ส่วนใหญ่ใช้ในการวัดค่าความเร็วคลื่นแรงเฉือนเพื่อใช้คำนวณหาค่าโมดูลัสแรงเฉือนที่ระดับความเครียดต่ำ โดยตัวแปรหลายตัวที่มีผลกระทบต่อการเคลื่อนที่ของคลื่นแรงเฉือนผ่านตัวอย่างดินนี้มีผลกระทบต่อพฤติกรรมของการเกิด Localization ด้วยเช่นเดียวกัน เช่น ค่าอัตราส่วนช่องว่างและสภาวะความเค้น เป็นต้น

ในงานวิจัยฉบับนี้จึงได้ทำการทดสอบตัวอย่างดินทรายท้องถิ่นและทรายซิลิกาในเครื่องทดสอบแรงอัดสามแกนที่มีการติดตั้งอุปกรณ์ตัว Bender Element ไว้เพื่อทำการตรวจวัดคลื่นแรงเฉือนระหว่างการกดทดสอบตัวอย่าง เพื่อใช้ศึกษาพฤติกรรมในเกิด Localization ในดิน โดยผลการทดสอบพบว่าเทคนิคการใช้คลื่นแรงเฉือนเพื่อดูพฤติกรรมการเกิดปรากฏการณ์ Localization นั้นสามารถอธิบายกระบวนการเกิดได้ดีในระดับหนึ่ง โดยความเร็วของคลื่นแรงเฉือนจะเริ่มลดลงจากค่าสูงสุด ณ ตำแหน่งความเครียดที่ประมาณ 0.5 – 3% ขึ้นอยู่กับสภาวะความเค้นและค่าความหนาแน่นเริ่มต้นของตัวอย่างดินนั้น การลดลงของค่าความเร็วคลื่นแรงเฉือนนี้อธิบายได้ว่าเป็นจุดเริ่มต้นของการเกิดปรากฏการณ์ Localization ขึ้นในมวลดิน

ภาควิชา .....วิศวกรรมโยธา.... ลายมือชื่อนิสิต ....
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PULPONG PONGVITHAYAPANU : STUDY OF LOCALIZATION IN SANDY SOIL USING SHEAR WAVE LOGGING. THESIS ADVISOR : ASSOCIATE PROFESSOR SUPOT TEACHAVORASINSKUN, D.ENG, 140 pp.

Strain localization phenomenon in soils has been one of the main research topics in geotechnical engineering for more than 50 years ago. Though investigations by theoretical and numerical studies can expose some of the strain localization characteristics but are impeded because of the complexity inside that localized zones. On the other hand, the experimental studies can obviously investigate that particular behavior in more details. Both conventional and new apparatuses, i.e. Gamma-ray, X-ray Computed Tomography and Digital Image Analysis, have been adopted in the strain localization analyses. However, those techniques require technical proficiency and experience in the installation, operation and result interpretation. The bender element test nowadays is becoming quite popular in geotechnical engineering because of its simplicity, relatively low cost and nondestructive test. A pair of bender elements has been extensively used to measure shear wave velocity for the determination of small strain shear modulus inside the soil sample. This shear wave propagation throughout the soil specimen influences in the same way by several of the same factors, e.g. void ratio and state of stress, compared to localization mechanism.

A series of compression triaxial tests implemented by bender element installation was performed to investigate the occurrence of strain localization in sand of various types, i.e. local and Silica sand. The results showed that this shear wave propagation technique can describe to some extent some characteristics of localization mechanism. The shear wave velocity tends to decrease from its maximum value at a certain strain level, i.e. 0.5 - 3% of global axial strain, depending on the state of stress as well as the initial packing condition of the sample. This diminution of shear wave velocity is the initiation of soil non-uniformity deformation or the onset of strain localization inside the sand specimen.

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LIST OF SYMBOLS

V_s	shear wave velocity
σ_c	failure stress in compression
σ_t	failure stress in tension
τ_{ult}	failure stress in pure shear
τ_f	shear strength per unit area
c	cohesion
σ_n	normal stress
ϕ	angle of shearing resistance
σ_c	normal stress at failure
τ_c	shear stress at failure
θ_c	angle between the major principal stress direction and shear band
θ_R	inclination angle between shear band and the major principal strain increment direction
θ_A	inclination angle of the shear bands which include the effects of friction angle and angle of dilatancy.
σ_1	major principle stress
σ_3	minor principle stress
$d\varepsilon_1$	major principal strain increment
$d\varepsilon_3$	minor principal strain increment
ψ	angle of dilatancy
d_{50}	mean grain size
U	uniformity coefficient
ρ_d	dry density
γ_d^{max}	maximum specific weight
γ_d^{min}	minimum specific weight
e	void ratio

e_{min} minimum void ratio

e_{max} maximum void ratio

D_r relative density

G_s specific gravity

t/s' stress ratio

ε_v volumetric strain

ε_1 axial strain

ε_a global axial strain

G_{max} small strain stiffness

L, L_{tr} tip-to-tip distance between transmitter and receiver of bender element

t travel time of the shear wave from transmitter to receiver

t_0 first time of arrival

t_{pp} time between first peak to peak

t_{cc}, τ time shift

$CC_{yx}(t)$ cross-correlation function

T total duration of the time record

dt change in time-of-flight in seconds

$d\theta$ change in phase angle in degrees

f frequency of the driving wave in Hertz

L_{tt} wave path length

λ wavelength

H/D slenderness ratio

σ'_c confining pressure

q' deviator stress

σ'_1 effective stress in the direction of shear wave propagation

σ'_3 effective stress in the direction of particle motion

σ'_{mean} mean state of stress

σ'_0 isotropic loading

α, β parameters include contact effects, void ratio, coordination number, fabric change and the loading history

A effect of grain properties

$F(e)$ influence of packing properties

C_n coordination number

Ω, Θ void ratio of the arrangement at constant fabric as well as the packing property

$\theta, \delta, \varsigma, \psi$ contact effect and the influence of fabric change

Ψ effect of void ratio

φ exponent parameter reflecting the contact behavior under anisotropic loading

q'/p' principal stress ratio