ANISOTROPIC STRENGTH AND STIFFNESS PROPERTIES OF HOT-MIXED ASPHALTIC CONCRETE (HMA)

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Abstract

This research is a study of the strength and deformation behavior of hot-mixed asphaltic concrete (HMA) that were prepared by different directions of compaction. The strength and deformation behaviors of HMA specimen were investigated by performing unconventional unconfined compression tests. The strength and small-strain stiffness as well as stress-strain properties were evaluated by performing continuous monotonic loading (ML) tests until failure, and ML tests by applying sustained loading (SL) followed by minute-amplitude cycles of unload and reload at several stages before failure. The vertical and horizontal strains were locally measured by means of a pair of local deformation transducers (LDTs) and a set of three clip gages, respectively. As a result, different Young's moduli and Poisson's ratios defined in this study were accurately determined. From test results, it could be seen that: 1) the strength and stiffness (E_{50}) of the vertically compacted HMA specimen were higher than those of the horizontally compacted HMA specimen; 2) at the same stress level, the vertical equivalent elastic Young's moduli, $E_{v,eq}$, were higher than the horizontal equivalent elastic Young's moduli, $E_{h,eq}$; 3) the vertical-to-horizontal Poisson's ratios, $\nu_{vh,eq}$, were higher than the horizontal-to-vertical Poisson's ratios, $\nu_{hv,eq}$; 4) the vertical equivalent elastic Young's moduli, $E_{v,eq}$, and horizontal equivalent elastic Young's moduli, $E_{h,eq}$, could be expressed in terms of hypoelasticity which the stiffness is a non-linear function with stress level; and 5) The $\nu_{vh,eq}$ and $\nu_{hv,eq}$-values were significantly related with the stress level (σ / σ_{max}) but were independent of density.

Keywords: Asphaltic concrete / Anisotropic / Compaction / Strength / Stiffness

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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษาพฤติกรรมทางด้านกำลังและการเสียรูปของวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในทิศทางที่แตกต่างกันโดยการทดสอบแบบแรงอัดทิศทางเดียวแบบไม่อัดตัวอย่าง การศึกษาพฤติกรรมความสัมพันธ์ระหว่างหน่วยแรงและความเครียดก่อนถึงจุดวิบัติและคุณสมบัติทางด้านกำลังและการเสียรูปทำโดยการให้แรงแบบต่อเนื่องและให้แรงโดยแทรกด้วยแรงคงค้างและต่อเนื่องด้วยแรงกระทำซ้ำแบบวงรอบวัฏจักร การวัดการเสียรูปของตัวอย่างแอสฟัลต์ติกคอนกรีตทำโดยการวัดแบบเฉพาะที่โดยใช้เครื่องมือวัดการเคลื่อนที่เฉพาะจุด (LDT) สำหรับวัดการเสียรูปในแนวแกนและเครื่องมือวัดการขยายตัวเฉพาะจุด (clip gage) สำหรับวัดการเสียรูปด้านข้าง ดังนั้นค่าโมดูลัสยืดหยุ่นและอัตราส่วนปัวซองในการศึกษานี้จึงเป็นค่าจริงที่ปราศจากการเสียรูปส่วนเพิ่มบริเวณผิวสัมผัส ผลการวิจัยพบว่าค่ากำลังรับแรงอัดของวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในทิศทางที่แตกต่างกันมีค่าไม่เท่ากัน โดยกำลังรับแรงอัดของวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในแนวตั้งมีค่ามากกว่าวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในแนวนอน ค่าโมดูลัสสมมูลย์และอัตราส่วนปัวซองสมมูลย์ของวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในแนวตั้งมีค่ามากกว่าค่าโมดูลัสสมมูลย์และอัตราส่วนปัวซองสมมูลย์ของวัสดุแอสฟัลต์ติกคอนกรีตที่ได้รับการบดอัดในแนวนอน ค่าโมดูลัสสมมูลย์สามารถแสดงได้ในรูปแบบไฮโปอิลาสติก (hypoelastic) ซึ่งมีความสัมพันธ์แบบไม่เป็นเส้นตรงกับระดับหน่วยแรง สำหรับอัตราส่วนปัวซองสมมูลย์สัมพันธ์กันกับระดับหน่วยแรงโดยที่ไม่ขึ้นกับความหนาแน่น

คำสำคัญ: แอสฟัลต์ติกคอนกรีต / แอนไอโซโทรปี / การบดอัด / กำลัง / สติฟเนส

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LIST OF SYMBOLS

A	=	temperature susceptibility
AC	=	asphaltic cements
AV	=	air voids
A_o	=	cross-sectional area of specimen before shearing
C	=	cohesion
CD	=	consolidated drained
CG	=	clip gage transducers
CL	=	cyclic loading
CRS	=	constant rate of strain
CTC	=	conventional triaxial compression
CTE	=	conventional triaxial extension
E	=	modulus of elasticity or Young's modulus
EP	=	electro pneumatic
E_{eq}	=	equivalent Young's modulus
E_h	=	horizontal Young's moduli
E_v	=	vertical elastic Young's moduli
E_0	=	initial Young's modulus
E_{50}	=	Elastic Young's modulus defined by the slope of relation between the stress and strain at the half of maximum stress
F	=	vertical force measured by load cell
e	=	void ratio
f(e)	=	void ratio function = $(2.17-e)^2/(1+e)$
G	=	shear modulus
G_s	=	specific gravity
g	=	acceleration due to gravity
H_0, L_0	=	initial height and length of the specimen
HMA	=	hot-mixed asphalt
ΔH, ΔL	=	changes in height and length of the specimen
IC	=	isotropic compression
K	=	bulk modulus
LDT	=	local deformation transducers
LVDT	=	Linear variable displacement transducer
M	=	total mass
M_B	=	mass of asphalt (binder)
M_{BA}	=	mass of absorbed asphalt, absorbed into the pores of the aggregate particles
M_{BE}	=	mass of effective asphalt, the asphalt binder between particles
M_G	=	mass of aggregate
ML	=	monotonic loading
m_h	=	slope of E_h / f(e) and σ_h / σ_0
m_v	=	slope of E_v / f(e) and σ_v / σ_0
OGFC	=	open-graded friction courses
P_B	=	asphalt content
P_{BE}	=	asphalt content
P_{BA}	=	asphalt absorption
PCC	=	Portland cement concrete

PI	=	penetration index
PSC	=	plane strain compression tests
p	=	mean stress
p'	=	mean effective stress
q	=	deviator stress
SL	=	sustained loading
SBS	=	styrene butadiene styrene
T	=	temperature
TC	=	triaxial compression
TE	=	triaxial extension
t	=	time
u	=	pore pressure
V	=	total volume of compacted mix
V_A	=	volume of air between the coated aggregate particles in the mix
V_B	=	volume of asphalt
V_{BA}	=	volume of absorbed asphalt
V_{BE}	=	volume of effective asphalt
V_G	=	volume of aggregate, the bulk volume including the aggregate pores
V_{GE}	=	effective volume of aggregate
V_{MM}	=	volume of voidless mix (maximum mix volume)
VFA	=	voids filled with asphalt
VMA	=	voids mineral aggregates
ρ	=	Density
σ_v	=	vertical stress
$\sigma_{v, max}$	=	maximum vertical stress
$\dot{\sigma}_v$	=	vertical stress rate
σ_h	=	horizontal stress
$\sigma_{h, max}$	=	maximum horizontal stress
$\dot{\sigma}_h$	=	horizontal stress rate
$\Delta\sigma_v$	=	vertical stress increments
$\Delta\sigma_h$	=	horizontal stress increments
ε	=	strain
ε_a	=	axial strain
ε_p	=	volumetric strain
ε_v	=	vertical strain
ε_h	=	horizontal strain
ε_q	=	triaxial shear strain
ε_r	=	lateral strain
ε_{vol}	=	volumetric strain in percentage
$\dot{\varepsilon}_v$	=	vertical strain rate
$\dot{\varepsilon}_h$	=	horizontal strain rate
$\Delta\varepsilon_v$	=	vertical strain increments
$\Delta\varepsilon_h$	=	horizontal strain increments
τ	=	shear strength
σ	=	normal stress
ν	=	Poisson's ratio
ν_{eq}	=	equivalent Poisson's ratio
ν_0	=	initial Poisson's ratio
ν_{vh}	=	Poisson's ratio for horizontal strain due to vertical strain

ν_{hv}	=	Poisson's ratio for vertical strain due to horizontal strain
ν_{hh}	=	Poisson's ratio for strain in any horizontal direction due to direct horizontal strain in the perpendicular direction
γ	=	bulk unit weight of soil