UNIVERSITI TEKNOLOGI MARA

ANISOTROPIC BEHAVIOR AND DEFORMATION OF COMPOSITE WEATHERED SANDSTONE AND SHALE UNDER DESTRUCTIVE AND NON-DESTRUCTIVE STRESSES

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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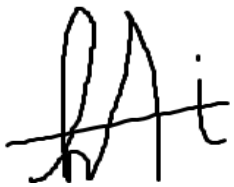

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ABSTRACT

The heterogeneity of interbedded weathered sandstone-shale sedimentary Kenny Hill formation is the major challenge for geotechnical engineers to evaluate this rock mass behavior, particularly, due to the anisotropy induced by the weathered shale bedding plane orientation and interbedded joint interface orientation. This study aimed to evaluate the anisotropic behavior and the micro-deformation of composite model that contribute to the interaction between two different stiffness rock material under destructive and non-destructive stresses. The destructive tests are; Point Load Test (PLT), Block Punch Test (BP), Direct Shear, Uniaxial, and Triaxial Compressive Strength. Meanwhile, the non-destructive tests are; rebound hammer, resistivity, Portable Ultrasonic Non-Destructive Indicator Test (PUNDIT), Free-Free Resonant Column (FFRC), real-time ultrasonic and real-time acoustic emission. The anisotropy of the weathered shale and composite model were measured with respect to the angles of bedding plane orientation (0º, 30º, 45º, 60º and; 90º) and the angles of joint orientation (30º, 45º, 60º and; 90º) respectively. The weathered sandstone V_P values are higher by 37% and 41% than composite and weathered shale respectively, while V_s values are higher by 74% and 61% than composite and weathered shale respectively. However, by increasing weathered shale angle of bedding plane orientation from 0º to 90º and composite joint orientation from 30º to 90º, the V_P and V_s decrease by 70% and 88% for weathered shale and by 35 % and 65 % for composite model respectively. The PLT and BI index strength of weathered sandstone is higher by 87% and 77% than the weathered shale respectively. Meanwhile, the index strength of weathered shale declined by 86% and 62% by decreasing the angle of bedding from 90º to 0º under PLT and BI respectively. The compressive strength of weathered sandstone is higher than composite C90 and weathered shale compressive strength by 75% and 77% under UC stress, 49% and 78% under 2 MPa confining pressure, and by 38% and 69% under 4 MPa confining pressure respectively. The failure criteria behavior of shale under compressive strength exhibit a remarkable alteration towards linear under 4 MPa confining pressure than undulant under UC stress due to the decrease in the maximum degree of strength anisotropy from 76% under UC stress to 41% under 4 MPa confining pressure. Meanwhile, the composite model displays a U shape failure criteria under (8 MPa, 12 MPa and; 20 MPa) confining pressure, however, the maximum degree of anisotropic strength increase from 16% under 8 MPa to 64% under 20 MPa for the reason of failure mode alteration of composite 60º angle of joint orientation under higher confining pressure. The failure mode of shale classified to failure along bedding (A.B) and failure cross bedding (C.B). Whereas, composite tend to fail along joint (A.J), cross joint (C.J) and cross bedding (C.B) within shale part. Therefore, the shear strength characteristics of bedding plane, shale rock material, joint interface and; composite rock material are defined accordingly. Eventually, the crack initiation (CI) stress levels are; (43%-80%), (53%-78%), and (35%-55%) of the peak stress while the crack damage (CD) stress levels are; (84%-97%), (78%-95%), and (75%-94%) of the peak stress for weathered sandstone, weathered shale and; composite respectively. The study significantly contributes to the influence of anisotropy on the geomechanical characteristics and deformation behavior of weathered sandstone-shale interbedded formation under various stress states with respect to joint orientation and the ratio of shale interlayer.

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In the Name of Allah, the Most Beneficent, the Most Merciful:

"All the praises and thanks be to Allah, Who has guided us to this, never could we have found guidance, were it not that Allah had guided us"

QURAN SURAH AL A'RAF (43)

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