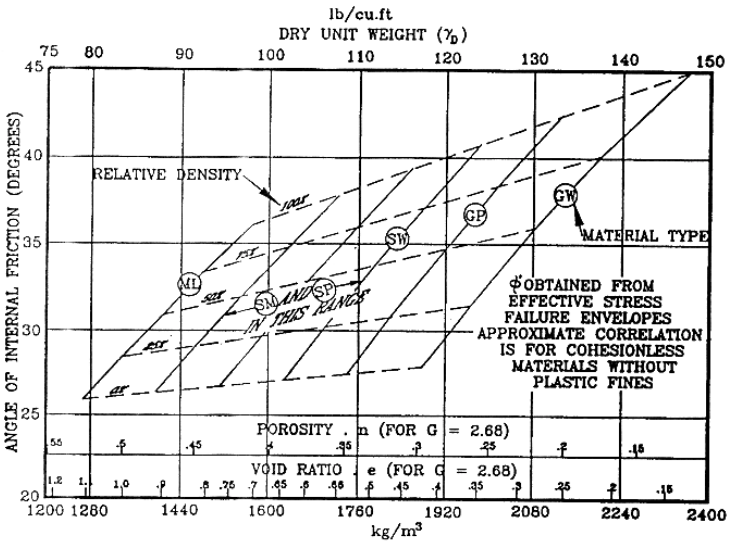


a. Angle of internal **friction versus unit weight (from NAVFAC DM-7 ref. A-1)**

Figure 3-5. Example correlations for properties of coarse-grained soils

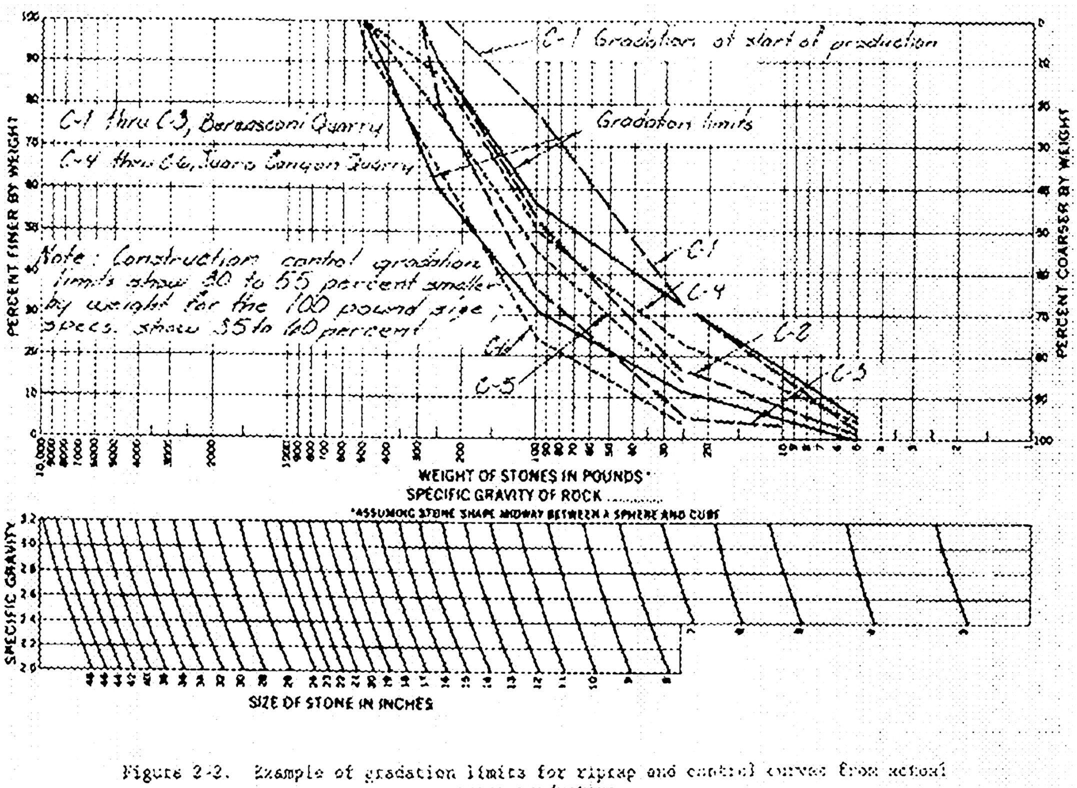
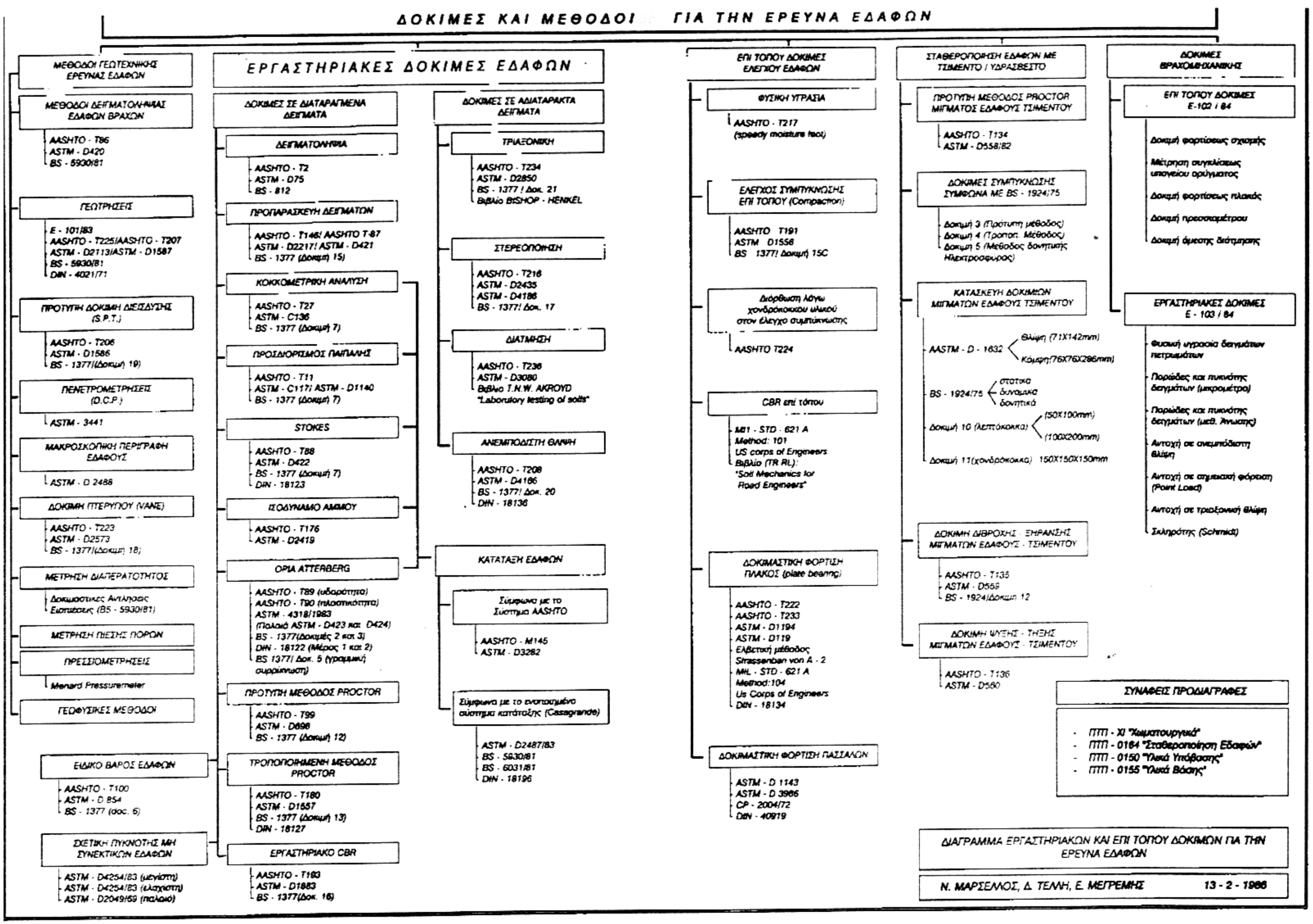


Figure 2-2. Example of gradation limits for riprap and control curves from actual stone production



ΔΟΚΙΜΕΣ ΚΑΙ ΜΕΘΟΔΟΙ ΓΙΑ ΤΗΝ ΕΡΕΥΝΑ ΕΔΑΦΩΝ
ΜΕΘΟΔΟΙ ΓΕΩΤΕΧΝΙΚΗΣ ΕΡΕΥΝΑΣ ΕΔΑΦΩΝ
ΜΕΘΟΔΟΙ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ ΕΔΑΦΩΝ ΒΡΑΧΩΝ
AASHTO - T86
ASTM - D420
BS - 5930/81
ΓΕΩΤΡΗΣΕΙΣ
E - 101/83
AASHTO - T225/AASHTO - T207
ASTM - D2113/ASTM - D1587
BS - 5930/81
DIN - 4021/71
ΠΡΟΤΥΠΗ ΔΟΚΙΜΗ ΔΙΕΙΣΔΥΣΗΣ (S.P.T.)
AASHTO - T206
ASTM - D1586
BS - 1377/(Δοκιμή 19)
ΠΕΝΕΤΡΟΜΕΤΡΗΣΕΙΣ (D.C.P.)
ASTM - 3441
ΜΑΚΡΟΣΚΟΠΙΚΗ ΠΕΡΙΓΡΑΦΗ ΕΔΑΦΟΥΣ
ASTM - D 2488
ΔΟΚΙΜΗ ΠΤΕΡΥΓΙΟΥ (VANE)
AASHTO - T223
ASTM - D2573
BS - 1377/(Δοκιμή 18)
ΜΕΤΡΗΣΗ ΔΙΑΠΕΡΑΤΟΤΗΤΟΣ
Δοκιμαστικές Αντλήσεις
Εισπιέσεις (BS - 5930/81)
ΜΕΤΡΗΣΗ ΠΙΕΣΗΣ ΠΟΡΩΝ
ΠΡΕΣΣΙΟΜΕΤΡΗΣΕΙΣ
Menard Pressuremeter
ΓΕΩΦΥΣΙΚΕΣ ΜΕΘΟΔΟΙ
ΕΡΓΑΣΤΗΡΙΑΚΕΣ ΔΟΚΙΜΕΣ ΕΔΑΦΩΝ
ΔΟΚΙΜΕΣ ΣΕ ΔΙΑΤΑΡΑΓΜΕΝΑ ΔΕΙΓΜΑΤΑ
ΔΕΙΓΜΑΤΟΛΗΨΙΑ
AASHTO - T2
ASTM - D75
BS - 812
ΠΡΟΠΑΡΑΣΚΕΥΗ ΔΕΙΓΜΑΤΩΝ
AASHTO - T146/ AASHTO T-87
ASTM - D2217/ ASTM - D421
BS - 1377 (Δοκιμή 15)
ΚΟΚΚΟΜΕΤΡΙΚΗ ΑΝΑΛΥΣΗ
AASHTO - T27
ASTM - C136
BS - 1377 (Δοκιμή 7)
ΠΡΟΣΔΙΟΡΙΣΜΟΣ ΠΑΙΠΑΛΗΣ
AASHTO - T11
ASTM - C117/ ASTM - D1140
BS - 1377 (Δοκιμή 7)
STOKES
AASHTO - T88
ASTM - D422
BS - 1377 (Δοκιμή 7)
DIN - 18123
ΙΣΟΔΥΝΑΜΟ ΑΜΜΟΥ
AASHTO - T176
ASTM - D2419
ΟΡΙΑ ATTERBERG
AASHTO - T89 (υδαρότητα)
AASHTO - T90 (πλαστικότητα)
ASTM - 4318/1983
(Παλαιό ASTM - D423 και D424)
BS - 1377(Δοκιμές 2 και 3)
DIN - 18122 (Μέρος 1 και 2)
BS 1377/ Δοκ. 5 (γραμμική συρρίκνωση)
ΠΡΟΤΥΠΗ ΜΕΘΟΔΟΣ PROCTOR
AASHTO - T99
ASTM - D698
BS - 1377 (Δοκιμή 12)
ΤΡΟΠΟΠΟΙΗΜΕΝΗ ΜΕΘΟΔΟΣ PROCTOR
AASHTO - T180
ASTM - D1557
BS - 1377 (Δοκιμή 13)
DIN - 18127
ΕΡΓΑΣΤΗΡΙΑΚΟ CBR
AASHTO - T193
ASTM - D1883
BS - 1377(Δοκ. 16)
ΕΙΔΙΚΟ ΒΑΡΟΣ ΕΔΑΦΩΝ
AASHTO - T100
ASTM - D 854
BS - 1377 (doc. 6)
ΣΧΕΤΙΚΗ ΠΥΚΝΟΤΗΣ ΜΗ ΣΥΝΕΚΤΙΚΩΝ ΕΔΑΦΩΝ
ASTM - D4254/83 (μεγίστη)
ASTM - D4254/83 (ελαχίστη)
ASTM - D2049/69 (παλαιό)
ΔΟΚΙΜΕΣ ΣΕ ΑΔΙΑΤΑΡΑΚΤΑ ΔΕΙΓΜΑΤΑ
ΤΡΙΑΞΟΝΙΚΗ
AASHTO - T234
ASTM - D2850
BS - 1377 / Δοκ. 21
Βιβλίο BISHOP - HENKEL
ΣΤΕΡΕΟΠΟΙΗΣΗ
AASHTO - T216
ASTM - D2435
ASTM - D4186
BS - 1377/ Δοκ. 17
ΔΙΑΤΜΗΣΗ
AASHTO - T236
ASTM - D3080
Βιβλίο T.N.W. AKROYD
"Laboratory testing of soils"
ΑΝΕΜΠΟΔΙΣΤΗ ΘΛΙΨΗ
AASHTO - T208
ASTM - D4166
BS - 1377/ Δοκ. 20
DIN - 18136
ΚΑΤΑΤΑΞΗ ΕΔΑΦΩΝ
Σύμφωνα με το Σύστημα AASHTO
AASHTO - M145
ASTM - D3282
Σύμφωνα με το ενοποιημένο σύστημα κατάταξης (Casagrande)
ASTM - D2487/83
BS - 5930/81
BS - 6031/81
DIN - 18196
ΕΠΙ ΤΟΠΟΥ ΔΟΚΙΜΕΣ ΕΛΕΓΧΟΥ ΕΔΑΦΩΝ
ΦΥΣΙΚΗ ΥΓΡΑΣΙΑ
AASHTO - T217
(speedy moisture test)
ΕΛΕΓΧΟΣ ΣΥΜΠΥΚΝΩΣΗΣ ΕΠΙ ΤΟΠΟΥ (Compaction)
AASHTO T191
ASTM D1556
BS 1377/ Δοκιμή 15C
Διόρθωση λόγω χονδρόκοκκου υλικού στον έλεγχο συμπύκνωσης
AASHTO T224
CBR επί τόπου
MIL - STD - 621 A
Method: 101
US corps of Engineers
Βιβλίο (TR RL):
"Soil Mechanics for Road Engineers"
ΔΟΚΙΜΑΣΤΙΚΗ ΦΟΡΤΙΣΗ ΠΛΑΚΟΣ (plate bearing)
AASHTO - T222
AASHTO - T233
ASTM - D1194
ASTM - D119
Ελβετική μέθοδος
Strassenban von A - 2
MIL - STD - 621 A
Method:104
Us Corps of Engineers
DIN - 18134
ΔΟΚΙΜΑΣΤΙΚΗ ΦΟΡΤΙΣΗ ΠΑΣΣΑΛΩΝ
ASTM - D 1143
ASTM - D 3966
CP - 2004/72
DIN - 40919
ΣΤΑΘΕΡΟΠΟΙΗΣΗ ΕΔΑΦΩΝ ΜΕ ΤΣΙΜΕΝΤΟ / ΥΔΡΑΣΒΕΣΤΟ
ΠΡΟΤΥΠΗ ΜΕΘΟΔΟΣ PROCTOR ΜΙΓΜΑΤΟΣ ΕΔΑΦΟΥΣ ΤΣΙΜΕΝΤΟΥ
AASHTO - T134
ASTM - D558/82
ΔΟΚΙΜΕΣ ΣΥΜΠΥΚΝΩΣΗΣ ΣΥΜΦΩΝΑ ΜΕ BS - 1924/75
Δοκιμή 3 (Πρότυπη μέθοδος)
Δοκιμή 4 (Τροποπ. Μέθοδος)
Δοκιμή 5 (Μέθοδος δονητικής Ηλεκτροσφύρας)
ΚΑΤΑΣΚΕΥΗ ΔΟΚΙΜΙΩΝ ΜΙΓΜΑΤΩΝ ΕΔΑΦΟΥΣ ΤΣΙΜΕΝΤΟΥ
AASTM - D - 1632
Θλίψη (71X142mm)
Κάμψη(76X76X286mm)
BS - 1924/75
στατικά
δυναμικά
δονητικά
Δοκιμή 10 (λεπτόκοκκα)
(50X100mm)
(100X200mm)
Δοκιμή 11(χονδρόκοκκα) 150X150X150mm
ΔΟΚΙΜΗ ΔΙΒΡΟΧΗΣ - ΞΗΡΑΝΣΗΣ ΜΙΓΜΑΤΩΝ ΕΔΑΦΟΥΣ - ΤΣΙΜΕΝΤΟΥ
AASHTO - T135
ASTM - D559
BS - 1924/Δοκιμή 12
ΔΟΚΙΜΗ ΨΥΞΗΣ - ΤΗΞΗΣ ΜΙΓΜΑΤΩΝ ΕΔΑΦΟΥΣ - ΤΣΙΜΕΝΤΟΥ
AASHTO - T136
ASTM - D560
ΔΟΚΙΜΕΣ ΒΡΑΧΟΜΗΧΑΝΙΚΗΣ
ΕΠΙ ΤΟΠΟΥ ΔΟΚΙΜΕΣ E-102 / 84
Δοκιμή φορτίσεως σχισμής
Μέτρηση συγκλίσεως υπογείου ορύγματος
Δοκιμή φορτίσεως πλακός
Δοκιμή πρεσσιομέτρου
Δοκιμή άμεσης διάτμησης
ΕΡΓΑΣΤΗΡΙΑΚΕΣ ΔΟΚΙΜΕΣ E - 103 / 84
Φυσική υγρασία δειγμάτων πετρωμάτων
Πορώδες και πυκνότης δειγμάτων (μικρομέτρο)
Πορώδες και πυκνότης δειγμάτων (μεθ. Άνωσης)
Αντοχή σε ανεμπόδιστη θλίψη
Αντοχή σε σημειακή φόρτιση (Point Load)
Αντοχή σε τριαξονική θλίψη
Σκληρότης (Schmidt)
ΣΥΝΑΦΕΙΣ ΠΡΟΔΙΑΓΡΑΦΕΣ
- ΠΤΠ - XI "Χωματουργικά"
- ΠΤΠ - 0164 "Σταθεροποίηση Εδαφών"
- ΠΤΠ - 0150 "Υλικά Υπόβασης"
- ΠΤΠ - 0155 "Υλικά Βάσης"
ΔΙΑΓΡΑΜΜΑ ΕΡΓΑΣΤΗΡΙΑΚΩΝ ΚΑΙ ΕΠΙ ΤΟΠΟΥ ΔΟΚΙΜΩΝ ΓΙΑ ΤΗΝ ΕΡΕΥΝΑ ΕΔΑΦΩΝ
Ν. ΜΑΡΣΕΛΛΟΣ, Δ. ΤΕΛΛΗ, Ε. ΜΕΓΡΕΜΗΣ 13 - 2 - 1986

ΠΙΝΑΚΑΣ 4 5.2

ΚΑΤΗΓΟΡΙΕΣ ΓΑΙΩΔΩΝ ΕΔΑΦΙΚΩΝ ΥΛΙΚΩΝ ΓΙΑ ΟΔΙΚΑ ΕΡΓΑ

(Δεν περιλαμβάνονται τα προϊόντα βραχωδών ορυγμάτων)

Κατηγορία εδαφικού υλικού	Χαρακτηριστικά υλικού	Όρια Atterberg	Max. πυκνότητα κατα την τροποποιημένη δοκιμη συμπύκνωσης χγρ/μ3	CBR*	Περιεκτικότητα σε οργανικα***	Παρατηρησεις ως προς τη δυνατότητα χρησιμοποίησής τους για επιχωματα
Ε1	Γαιώδες υλικό με μέγιστη διάσταση κόκκου D < 200 χλστ και περιεκτικότητα σε κόκκους 200 > D > 150 χλστ μέχρι 25%	LL < 40 ή LL < 65 και PI>(0.6LL-9)	> 1.600	> 3 και διόγκωση** < 3%	< 2%	Αποδεκτό
Ε2	Μέγιστος κόκκος < 100 χλστ Διερχόμενο % από Νο 200 < 35%	LL < 40	> 1 940	> 5 και διόγκωση** <2%	< 1%	Κατάλληλο
Ε3	Μέγιστος κόκκος < 80 χλστ Διερχόμενο % από Νο 200 < 25%	LL < 30 PI < 10	-	> 10 και διόγκωση** = 0	0%	Επίλεκτο I
Ε4	Μέγιστος κόκκος < 80 χλστ Διερχόμενο % από Νο 200 < 25%	LL < 30 PI < 10	-	> 20 και διόγκωση** = 0	0%	Επίλεκτο II
Ε0	Εδαφικό υλικό που δεν ανήκει στις άλλες κατηγορίες					Ακατάλληλο

LL = Όριο Υδαρότητας E 105 - 86 Method 5

PI = Δείκτης Πλαστικότητας E 105 - 86 Method 6

Νο 200 = Κόσκινο της Αμερικανικής σειράς προτύπων κόσκινων AASHTO : M-92 ανοίγματος βροχίδας 0,074 χλστ

*CBR = Τιμή του Καλιφορνιακού Λόγου Φέρουσας Ικανότητας που προσδιορίζεται σύμφωνα με τη μέθοδο 12 των Προδιαγραφών Εργαστηριακών Δοκιμών Εδαφομηχανικής (Ε 105-86) επί δοκιμίων συμπυκνωθέντων στο 90% της μέγιστης πυκνότητας της Τροποποιημένης Δοκιμής Συμπύκνωσης (Μέθοδος 11 Ε 105-86) με τη βέλτιστη υγρασία και μετά από υδρεμποτισμό 4 ημερών. Κατ' εξαίρεση επί "*σιμεντωμένων*" εδαφών και για έργα σε όρυγμα, για τον υπολογισμό της φέρουσας ικανότητας της "*υποκείμενης στρώσης*" οδοστρωμάτων θα γίνεται συμπληρωματικά και προσδιορισμός του CBR με δοκιμή "*επί τόπου*"

** = Κατά τη δοκιμή CBR

*** = Θα προσδιορισθεί με τη μέθοδο της "*υγρής οξείδωσης*" (AASHTO T 194)

ΠΙΝΑΚΑΣ ΣΤ.1

ΚΑΤΑΤΑΞΗ ΚΑΤΑΛΛΗΛΟΤΗΤΑΣ ΕΔΑΦΙΚΩΝ ΥΛΙΚΩΝ ΓΙΑ ΕΠΙΧΩΜΑΤΑ

ΓΕΝΙΚΗ ΤΑΞΙΝΟΜΗΣΗ	ΚΟΚΚΩΔΕΣ ΥΛΙΚΟ (35% ή μικρότερο διερχόμενο από το No. 200)							ΙΛΥΩΔΗ – ΑΡΓΙΛΙΚΑ ΥΛΙΚΑ (περισσότερο από 35% διερχόμενο από το No. 200)			
ΟΜΑΔΑ ΤΑΞΙΝΟΜΗΣΗΣ	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
ΚΟΚΚΟΜΕΤΡΙΚΗ ΑΝΑΛΥΣΗ, επί τοις % ΔΙΕΡΧΟΜΕΝΑ											
No. 10	50 max.										
No. 40	30 max.	50 max.	51 min.								
No. 200	15 max.	25 max.	15 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
ΧΑΡΑΚΤΗΡΙΣΤΙΚΑ ΥΛΙΚΟΥ ΔΙΕΡΧΟΜΕΝΑ ΑΠΟ ΤΟ ΚΟΣΚΙΝΟ No 40:											
ΟΡΙΟ ΥΔΑΡΟΤΗΤΟΣ				40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
ΔΕΙΚΤΗΣ ΠΛΑΣΤΙΚΟΤΗΤΑΣ	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.[1]
ΔΕΙΚΤΗΣ ΟΜΑΔΟΣ	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.
ΠΕΡΙΓΡΑΦΗ ΤΟΥ ΤΥΠΟΥ ΤΟΥ ΥΛΙΚΟΥ ΜΕ ΒΑΣΗ ΤΑ ΚΥΡΙΑ ΧΑΡΑΚΤΗΡΙΣΤΙΚΑ ΤΟΥ	Βραχώδη κομμάτια, λεπτά χαλίκια & άμμος		Ιλυώδη ή Αργιλικά Χαλίκια και Άμμος					Ιλυώδη Εδαφικά Υλικά		Αργιλικά Εδαφικά Υλικά	
ΚΑΤΑΤΑΞΗ ΥΛΙΚΟΥ	ΕΞΑΙΡΕΤΙΚΑ έως ΚΑΛΑ							ΜΕΤΡΙΑ έως ΦΤΩΧΑ ή και ακατάλληλα			

Διαδικασία Ταξινόμησης: Με τα διαθέσιμα αποτελέσματα, προχωρούμε από αριστερά προς τα δεξιά στον πίνακα και η σωστή ομάδα θα βρεθεί με τη μέθοδο του αποκλεισμού. Η πρώτη ομάδα από τα αριστερά, μέσα στην οποία τα αποτελέσματα θα ταιριάζουν, είναι η σωστή ταξινόμηση.

[1] Ο Δείκτης πλαστικότητας της υποομάδας του A-7-5 είναι ίσος ή μικρότερος του LL μείον 30.
Ο Δείκτης πλαστικότητας της υποομάδας του A-7-6 είναι μεγαλύτερος του LL μείον 30.

TABLE 8.16 RECOMMENDED REQUIREMENTS FOR COMPACTION AND SLOPES OF HIGHWAY EMBANKMENTS.

		Condition of Exposure					
		Condition 1 (Not Subject to Inundation)			*Condition 2 (Subject to Inundation)*		
Revised Public Roads System	*Approximate Equivalent, Unified System*	*Height of Fill, feet*	*Side Slope*	*Desired Compaction, % AASHO Maximum Density*	*Height of Fill, feet*	*Side Slope*	*Desired Compaction, % AASHO Maximum Density*
A-1	GW, GP, SW, some GM or SM	Not critical	$1\frac{1}{2}$ to 1	95+	Not critical	2 to 1	95
A-3	SP	Not critical	$1\frac{1}{2}$ to 1	100+	Not critical	2 to 1	100+
A-2-4 A-2-5	Most GM and SM	Less than 50	2 to 1	95+	Less than 10 10 to 50	3 to 1	95 95–100
A-2-6 or 7	GC or SC	Less than 50	2 to 1	95+	Less than 50	3 to 1	95–100
A-4, A-5	ML, MH	Less than 50	2 to 1	95+	Less than 50	3 to 1	95–100
A-6, A-7	CL, CH	Less than 50	2 to 1	95–100	Less than 50	3 to 1	95–100

Notes:

(1) Under Condition 2, higher fills on the order of 35 to 50 ft should be compacted to 100 percent at least for portions subject to inundation. Major fills composed of unusual materials which have low shearing resistance should be analyzed by soil mechanics methods.

(2) For soils of the A-6 or A-7 groups, the lower compaction requirements shown obtain only for low fills (10 to 15 ft or less) not subject to inundation and not carrying large volumes of heavy traffic.

(3) Highly organic soils are not generally suitable for fill construction.

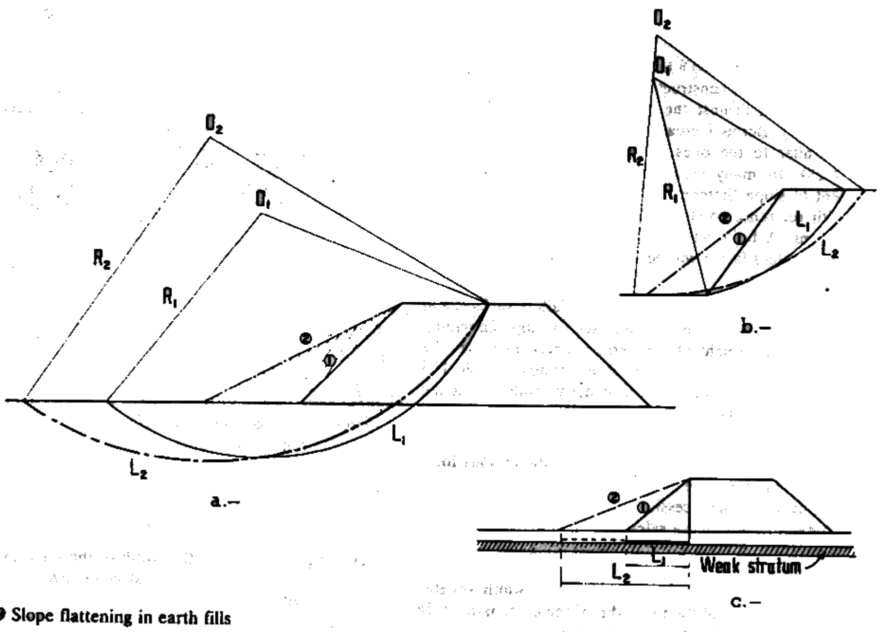


Fig. 6-49 Slope flattening in earth fills

Table 6-5
Slopes recommended for cuts

TYPE OF MATERIAL	RECOMENDED SLOPE (HORIZONTAL DISTANCE: VERTICAL DISTANCE)				OBSERVATIONS
	Up to 5m (16ft)	From 5 to 10m (16 to 33ft)	From 10 to 15m (33 to 50ft)	Greater than 15m (50ft)	
Sound massive granite	1/4:1, H	1/4:1, H	1/4:1, H	1/4:1, H	Remove the weathered part at the crest at 1/2:1 (if there is any).
Blocky sound fissured granite	1/4:1, H	1/4:1, H	1/2:1, H	1/2:1, H	Remove loose blocks according to the layout of the fissures
Exfoliated granite; large blocks packed in sand	1/2:1, H	3/4:1, H	3/4:1, H	3/4:1, H	Construction of berm at the change of the slope not considered advisable if the weathered part at the crest is removed at 1/2:1.
Exfoliated granite; large blocks in a matrix of sandy clay	1/2:1, H	3/4:1, 1/2:1, H, H/2	H/2, 3/4:1, 1m, 1/2:1, H/2	H>15, 3m, 3/4:1	Construction of toe berm recommended to catch the small surficial slides that usually occur.
Fully weathered granite	3/4:1, H	1:1, 3/4:1, H, H/2	1:1, H	1:1, H	If the product of the weathered granite is fine silty or clayey sand, a 1m (3.3ft) foot berm is recommended for cuts up to 15m (50ft) and a 3m (10ft) foot berm for larger cuts.
Diorities	The same observations as for granites, depending on the degree of weathering of the rock.				
Unweathered fissured andesite	1/4:1, H	1/4:1, H	1/4:1, H	1/4:1, H	Loose block removal following the fissure planes is recommended
Fractured, slightly weathered andesite	1/2:1, H	1/2:1, H	1/2:1, H	3/4:1, 4m, H, 1/2:1, H/2	A 4m (13ft) berm can be built at the slope, change if the lower part of the cut does not contain clay in the fractures and the fractures are closed.
Fractured, weathered andesite	1/2:1, H	3/4:1, H	3/4:1, H	3/4:1, H	It is advisable to remove the crest at a slope of 1:1. (the most highly weathered part). If there is seepage, adequate subdrainage must be planned.

Table 6-5
(continued)

TYPE OF MATERIAL	RECOMENDED SLOPE (HORIZONTAL DISTANCE: VERTICAL DISTANCE)				OBSERVATIONS
	Up to 5m (16ft)	From 5 to 10m (16 to 33ft)	From 10 to 15m (33 to 50ft)	Greater than 15m (50ft)	
Sound or fractured rhyolites in large blocks with fracture systems at 90°, horizontally and vertically.	1/4:1	1/4:1	1/4:1	1/4:1	Loose block removal following the fracture planes is recommended; also removal of the weathered part at the crest at 1:1.
Sound, slightly fractured diabase	1/4:1	1/4:1	1/4:1	1/4:1	Loose block removal is recommended
Sound fractured basalt	1/4:1	1/4:1	1/4:1	1/4:1	Remove the crest of the cut at 1/2:1 if fracturing is very intense. If there is a weathered layer, remove at 1:1.
Fractured basalt in blocks of all sizes	3/4:1	3/4:1	3/4:1	1:1	If the fragments are loose and without soil, or packed in clay or soft silt with water flow.
Fractured basalt in blocks of all sizes	1/2:1	1/2:1	1/2:1; 1:1 (H/2 – H/2)	1/2:1; 1:1 (H/2 – H/2)	If the fragments are packed in firm clay with no seepage
Very fractured, highly weathered basalt	1/2:1	1/2:1	3/4:1	3/4:1	In very rainy areas, construction of a 1m (3.3ft) foot berm for cuts up to 15m (50ft) and 3.0m (10ft) foot berm for cuts larger than 15m (50ft) is recommended at the toe of the slope.
Basaltic flows interbeded with pyroclastic rocks	Basalt; Pyroclastics 1:1	Definition of the contact between the basalt and the pyroclastic rocks is needed, so the coresponding slope can be given for each. Pyroclastic rocks require a 1:1 slope when loose or 3/4:1 when compact or for very coarse materials.			
Massive basalt Pyroclastic Rocks	1/2:1	3/4:1	3/4:1	3/4:1; 1:1 (H/2 – H/2)	If the basalt pyroclastic rock is fine-grained and loose, the same recommendations apply as for the other pyroclastics.
Sound or slightly fissured tuffs and brecciated, andesitic, rhyolitic or basaltic tuffs.	1/4:1	1/4:1	1/4:1	1/4:1	If they are weathered in the upper portion of the cut, it is advisable to remove the crest at 1/2:1.
Sound or slightly fissured tuffs and brecciated, andesitic, rhyolitic or basaltic tuffs.	1/4:1	1/4:1	1/4:1	1/4:1	If there is a large water flow, construction of a 4m (13ft) waterproofed berm half way up is recommended.

Table 6-5
(continued)

TYPE OF MATERIAL	RECOMENDED SLOPE (HORIZONTAL DISTANCE: VERTICAL DISTANCE)				OBSERVATIONS
	Up to 5m (16ft)	From 5 to 10m (16 to 33ft)	From 10 to 15m (33 to 50ft)	Greater than 15m (50ft)	
Slightly weathered tuffs and brecciated, rhyolitic, andesitic or basaltic tuffs.	1/4:1	1/2:1	1/2:1	1/2:1	Removal of the upper part of the crest at 3/4:1 is recommended if there is intense fracturing or weathering.
Highly weathered tuffs and brecciated, rhyolitic, basaltic or andesitic tuffs.	1/2:1	1/2:1	3/4:1	1:1 (H/2); 3/4:1 (H/2)	Change in slope half way up cuts deeper than 15m (50ft).
Hard, firm, slightly fractured clay-shale with almost horizontal dip.	1/4:1	1/4:1	1/4:1	1/2:1 (H/2); 1/4:1 (H/2)	Do not excavate crest ditches if not thoroughly impermeable. Remove the topmost weathered portion of the crest at 3/4:1.
Soft, medium-strength, highly fractured clay-shale	1/2:1	3/4:1	3/4:1	1:1 (H/2); 3/4:1 (H/2)	Do not excavate crest ditches if not thoroughly impermeable. Remove the most weathered part of the crest at 1:1.
Strongly cemented sound sandstones, poorly defined stratification, horizontal or dipping to the cut.	1/4:1	1/4:1	1/4:1	1/4:1	Remove the weathered portion of the crest at 3/4:1.
Poorly cemented, highly weathered sandstone, with seepage.	1/4:1	1/4:1	1/2:1	3/4:1 (H/2); 1/2:1 (H/2)	Remove the weathered portion of the crest at 1:1
Well-cemented brecciated conglomerate with siliceous or calcareous matrix.	1/8:1	1/4:1	1/4:1	1/4:1	Removal of all loose fragments is recommended
Poorly cemented conglomerate with clayey matrix	1/2:1	3/4:1	1:1 (H/2); 3/4:1 (H/2)	1:1 (H/2); 3/4:1 (H/2)	If the clayey matrix is saturated or subjected to marked changes in moisture, construction of a 1m (3.3ft) foot berm is recommended for cuts deeper than 10m (33ft), with 4m (13ft) berms half way up.
Fractured limestone with thick or poorly defined stratification dipping toward the cut.	1/4:1	1/4:1	1/4:1	1/4:1	Removal of the weathered or very fractured upper portion of the crest at 1:1 is recommended.
Sound limestones with thin horizontal stratification dipping toward the cut.	1/4:1	1/2:1	1/2:1	3/4:1 (H/2); 1/2:1 (H/2)	Remove to 1:1 the upper portion

Table 6-5
(continued)

TYPE OF MATERIAL	RECOMENDED SLOPE (HORIZONTAL DISTANCE: VERTICAL DISTANCE) Up to 5m (16ft)	From 5 to 10m (16 to 33ft)	From 10 to 15m (33 to 50ft)	Greater than 15m (50ft)	OBSERVATIONS
Weathered limestone with seepage	1/2:1	3/4:1	3/4:1	3/4:1	Plan for subdrainage and impermeable crest ditches
Unweathered limestone with dip between 90° and 45° to the outside of the cut, with clay between strata.	Give the slope corresponding to the dip. If the rock is highly fractured, design waterproofed 4m (13ft) berm half way up. Impermeable crest ditches.				
Very fractured weathered limestone	3/4:1	3/4:1	1:1 (H/2); 3/4:1 (H/2)	1:1 (H/2); 3/4:1 (H/2)	Impermeable crest ditch
Slightly fractured unweathered limestone, with dip between 30° and 45° to the outside of the cut.	1/8:1	1/4:1	1/4:1	1/4:1	Can be regarded as though the dip were horizontal
Very slightly weathered and fractured limestone with dip between 45° and 30° to the outside of the cut.	1/2:1	1/2:1	3/4:1	3/4:1	Remove the most fractured portion at 1:1. Waterproofed crest ditch.
Slates	Same recommendations as for limestones				
Moderately compact aglomerate with non-plastic fines	3/4:1	3/4:1	1:1 (H/2); 3/4:1 (H/2)	1:1 (H/2); 3/4:1 (H/2)	Waterproofed crest ditch. For cuts deeper than 10 m (33 ft), construct 1m (3.3 ft) berm at toe of slope.
Moderately compact aglomerate with plastic fines	3/4:1	3/4:1	3/4:1 (H/2); 2m; 3/4:1 (H/2)	1:1 (H/2); 4m; 3/4:1 (H/2)	Waterproofed crest ditches. For cuts deeper than 10m (33ft), design a 2m (6.6ft) berm half way up and for cut deeper than 15m (50ft) increase the width to 4m (13ft).
Silty sands and compact silts	1/2:1	3/4:1	3/4:1	3/4:1	Remove the upper more weathered portion at 1:1. If the materials are susceptible to erosion, a slope of 1:1 should be designed and protected with grass.
Silty sands and not very compact silts	1:1	1:1	11/4:1	11/4:1	Impermeable crest ditch. Remove the most weathered part at 1.5:1. For cuts greater than 15m (50ft), design a 3m (10ft) berm at the toe of the slope.

Table 6-5
(continued)

TYPE OF MATERIAL	RECOMENDED SLOPE (HORIZONTAL DISTANCE: VERTICAL DISTANCE)				OBSERVATIONS
	Up to 5m (16ft)	From 5 to 10m (16 to 33ft)	From 10 to 15m (33 to 50ft)	Greater than 15m (50ft)	
Silty sands and very compact silts	1/4:1, H	1/4:1, H	1/2:1, H	3/4:1, H/2; 1/4:1, H/2	Remove the loose upper portion to 1.5:1
Firm, slightly sandy clays (homogeneous)	1/2:1, H	1/2:1, H	3/4:1, H/2; 1/2:1, H/2	3/4:1, H/2; 1/2:1, H/2	Remove the weathered part at 1:1. If there is seepage, plan subdrainage.
Very soft compressible clays	1:1, H	1 1/4:1, H	1 1/2:1, H	1 1/2:1, H	*For cuts deeper than 15m (50ft), design well-drained berm half way up
Kaolin derived from the weathering of granites or diorites	1:1, H	1 1/2:1, H	1 1/2:1; 6m; 1 1/2:1, 8m		Cover the slope with grass for cuts deeper than 8m (26ft) and design a well-drained 6m (20ft) berm. (maximum height 16m) (53ft).
Clean sands, loose to firm	Angle of internal friction with 1.00m (3.3ft) berm at the base.				Cover the slopes with grass

* The berm will have to be constructed with waterproofed ditches. If these are not impermeable, seepage could occur which would endanger the lower portion of the cut by establishing a failure surface caused by the resulting reduction in the shear strength of the material.

Table 6-6, [2], is a comprehensive summary of the factors causing slides and their mechanisms.

Work done by the engineer and the constructors can often be the cause of serious slope stability problems. The following [8] is a list of the construction processes that most often cause instability problems:

1. Modification of the natural conditions of seepage due to fills, ditches or excavations
2. Overloading of weak strata due to fill, and sometimes waste
3. Overloading of soils with weak stratification planes due to fill
4. Removal, by cutting, of a thin stratum of permeable material which acts as a natural draining blanket of the soft clay
5. Detrimental increase in seepage pressures or orientation of seepage forces when changes occur in the direction of seepage, as a result of cuts or fills
6. Exposure of hard fissured clays to air and water, due to cuts
7. Removal of surface layers of soil due to stripping or excavation, which may cause layers of the same stratum further uphill to slide over the underlying layers of harder soil or rock
8. Increase in hydrostatic loads or hydraulic heads below the surface of a cut when its bed is covered with an impermeable layer

Generally speaking, the causes of slides can be external or internal. External causes bring about an increase in the acting shear stresses, without altering the shear strength of the material. Causes of this type are an increase in the height or steepness of the slope, any structural load or embankment that is placed on the crest of the slope and earthquakes. Internal causes are those which occur without any change in the external conditions of the slope. They are always associated with a loss of shear strength of the soil. An increase in pore pressure or dissipation of cohesion by weathering are causes of this type.

Table 6-7 [8] gives the factors that most commonly lead to an increase in acting shear stresses in a natural or artificial slope. Table 6-8 [8] gives the factors that most often cause a reduction in the shear strength of the materials of natural and artificial slopes.

Table 6-6
Factors causing slides [2]

AGENT	ACTIVATING PROCESS	WAY IN WHICH AGENT ACTS	MOST SUSCEPTIBLE MATERIALS	PHYSICAL NATURE OF ACTION	EFFECTS ON STABILITY
Erosion and transport	Construction processes or erosion	Increases height or steepness of slope	All Materials	Changes in state of stress	Increase in shear stresses
			Stiff or fissured clays, clay-shales	Changes in state of stress and opening of fissures	Increase in shear stresses. Process § is triggered
Tectonic forces	Tectonic movement	Large deformations in the earth's crust	All materials	Increase in angle of slope	Increase in shear stresses
Tectonic forces or the use of explosives	Earthquakes or blasting	High frequency vibrations	All materials	Transient loading	Increase in shear stresses
			Loess, slightly cemented sands and gravels	Alteration of interparticle bonds	Reduction in cohesion and increase in shear stresses
			Fine or medium grained sand, loose and saturated	Rearrangement of particles	Liquefaction
Weight of the slope material	Construction of the slope	Surface slide	Hard or fissured clay, clay-shale, remains of old slides	Opening of closed fissures and creation of new fissures	Reduction in cohesion. Process § is accelerated
		Slide in weak strata at toe of slope	Hard materials on soft strata		
Water	Rain or thaw	Removal of air from the voids	Moist sand	Increase in pore water pressure	Drop in strength
		Removal of air from open joints	Jointed rock, clay-shales		
		§) Reduction in capillary tension associated with expansion	Hard and fissured clays, some clay-shales	Expansion	Reduction in cohesion
		Chemical decay	Any rock	Weakening of interparticle bonds	
	Freezing of the ground	Expansion of water by freezing	Jointed rock	Opening of closed fissures and creation of new fissures	Reduction in cohesion
		Formation of ice lenses in the soil	Silts and sandy silts	Increase in water content of the frozen soil	Reduction in frictional strength
	Period of drought	Shrinkage	Clay	Cracking by shrinkage	Reduction in cohesion
	Drawdown	Flow towards the toe of the slope	Silts and fine sands	Increase in pore water pressure	Reduction in frictional strength
	Fluctuations in the phreatic level	Rearrangement of particles	Medium to fine grained sands, loose, saturated	Increase in pore water pressure	Liquefaction
	Rise in the phreatic level of a distant aquifer	Rise in the hydraulic head of the slope material	Strata of sand or silt between or below strata of clay	Increase in pore water pressure	Reduction in frictional strength
	Internal water flow or seepage	Seepage toward the slope	Saturated silt	Increase in pore water pressure	Reduction in frictional strength
		Removal of air from the voids	Moist fine sand	Dissipation of surface tension	Reduction in cohesion
		Removal of soluble cementing agents	Loess	Weakening of the interparticle bonds	
		Internal erosion	Silt or fine sand	Piping	Increase in shear stresses