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ΕΤΑΙΡΕΙΑ
ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ
& ΓΕΩΤΕΧΝΙΚΗΣ
ΜΗΧΑΝΙΚΗΣ

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Αρ. 149 – ΑΠΡΙΛΙΟΣ 2021

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Καλή Ανάσταση και Καλό Πάσχα

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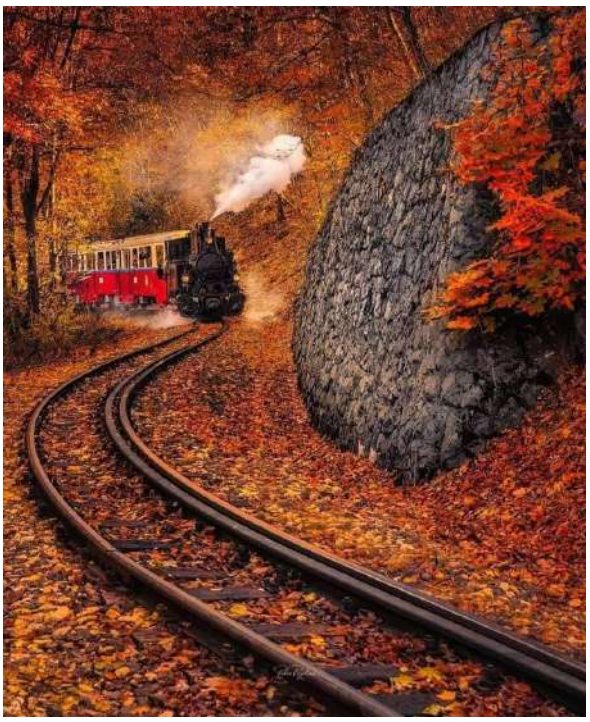


Τραινάκι Πηλίου

ΟΙ ΣΕΙΣΜΟΙ ΤΗΣ 3ης & 4ης ΜΑΡΤΙΟΥ 2021 ΣΤΗΝ ΘΕΣΣΑΛΙΑ

ΟΙ ΣΕΙΣΜΟΙ ΤΗΣ ΘΕΣΣΑΛΙΑΣ
Μ6.3, 3 Μαρτίου 2021 και Μ6.1, 4 Μαρτίου 2021
Προκαταρκτική έκθεση

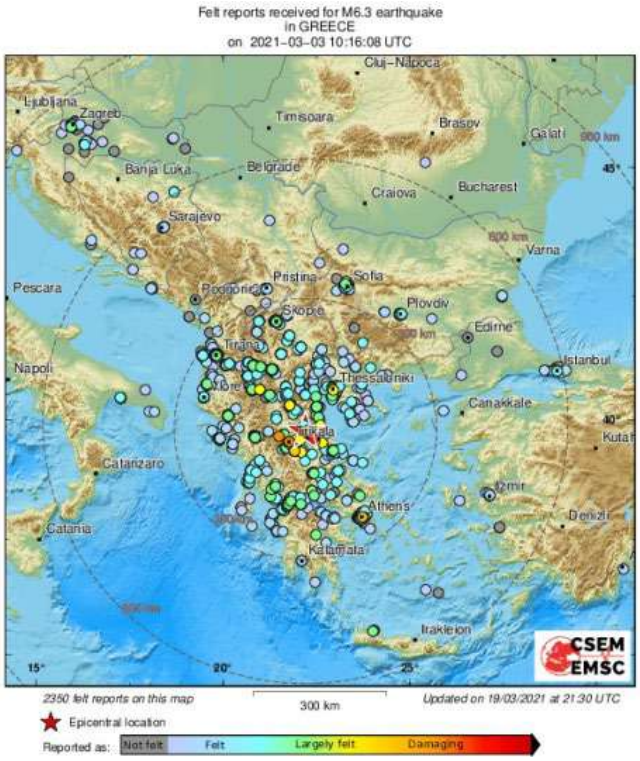
ΙΣΧΥΡΗ ΕΔΑΦΙΚΗ ΔΟΝΗΣΗ
ΣΥΜΠΕΡΙΦΟΡΑ ΕΔΑΦΟΥΣ ΚΑΙ ΚΑΤΑΣΚΕΥΩΝ

Karakostas, C., Klimis, N, Lekidis, V., Makra, K., Margaris, B,, Morfidis, K., Papaioannou, C., Rovithis, E., Salonikios, T., Sotiriadis, D., Theodoulidis, N.

1. ΙΣΧΥΡΗ ΣΕΙΣΜΙΚΗ ΚΙΝΗΣΗ

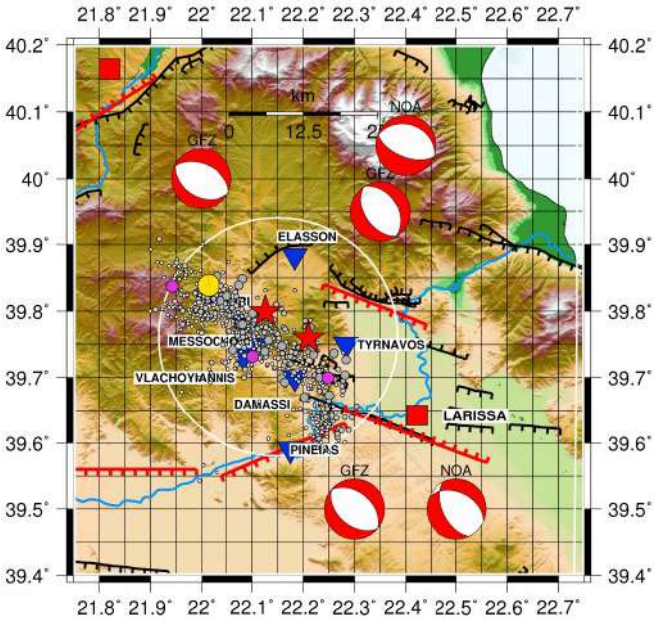
1.1 Γενικά Στοιχεία

Την 3η Μαρτίου 2020 και ώρα Ελλάδας 12:16 σημειώθηκε στη Θεσσαλία ισχυρή σεισμική δόνηση μεγέθους Mw6.3. Σύμφωνα με την ανακοίνωση του Εθνικού Σεισμογραφικού Δικτύου επρόκειτο για επιφανειακό (h~8 km) σεισμό με το επίκεντρο του να εντοπίζεται στη περιοχή το Τυρνάβου σε απόσταση περίπου 22 km ΔΒΔ από τη Λάρισα και 8 km από τον Τύρναβο. Ενδεικτικά οι γεωγραφικές συντεταγμένες του επικέντρου όπως δίνονται από την ιστοσελίδα του Σεισμολογικού Σταθμού του ΑΠΘ (http:// http://geophysics.geo.auth.gr/ss) είναι 39.7320Β 22.2180Α. Στις 13:45 έγινε ένας μετασεισμός Mw5.1. Την 4η Μαρτίου στις 20:31 έγινε ένας ακόμη ισχυρός σεισμός με μέγεθος Mw6.1. Ο ισχυρότερος σεισμός (μέχρι 16.03.2021) έγινε την 12η Μαρτίου με μέγεθος Mw5.6. Ο σεισμός αυτός έγινε στο βορειοδυτικό άκρο της ζώνης διάρρηξης.



Εικόνα ΣΕΙΣ1. Χάρτης αισθητότητας του σεισμού της 3ης Μαρτίου από την απόκριση των κατοίκων.

Ο χάρτης του σχήματος ΣΕΙΣ1 δίνει τη χωρική κατανομή της αισθητότητας με βάση την απόκριση των κατοίκων στην εδαφική κίνηση όπως αυτή αποτυπώθηκε ηλεκτρονικά στο Ευρω-Μεσογειακό Σεισμολογικό Κέντρο (https://static2.emsc.eu/Images/FELTREPORTS/95/954327/Intensity Map.png). Από το χάρτη αυτό φαίνεται ότι ο σεισμός έγινε αισθητός κατά τη ΒΔ διεύθυνση μέχρι το Sarajevo και το Zagreb, ενώ ΝΑ σε σημαντικά μικρότερη απόσταση όπως μέχρι τη Κορινθία και την Αττική. Ο σεισμός έγινε επίσης ιδιαίτερα αισθητός στη Θεσσαλονίκη και στην Κ. Μακεδονία.



Εικόνα ΣΕΙΣ2. Γεωγραφική κατανομή των επικέντρων των δύο σεισμών (κόκκινα άστρα) και των μετασεισμών για τις 16 ημέρες. (Πηγή: geophysics.geo.auth.gr). Τα κόκκινα άστρα είναι τα επίκεντρα των δύο σεισμών με M>6.0. Οι μηχανισμοί γένεσης από δύο σεισμολογικά κέντρα και τα γνωστά ρήγματα (Παπαζάχος και συν. 2001; και Γκανάς και συν.2020) δίνονται επίσης.

Ο χάρτης ΣΕΙΣ2 δίνει τη γεωγραφική κατανομή των επικέντρων των δύο ισχυρών σεισμών της 3ης και 4ης Μαρτίου (κόκκινα άστρα), το επίκεντρο του σεισμού της 12ης Μαρτίου (κίτρινος κύκλος) και τα επίκεντρα των μετασεισμών με M>3.0 (geophysics.geo.auth.gr). Η χωρική κατανομή των επικέντρων φαίνεται να ορίζει μία ζώνη με διεύθυνση ΒΔ-ΝΑ, η οποία είναι σε καλή συμφωνία με τους μηχανισμούς γένεσης, τη διεύθυνση των μεγάλων ρηγμάτων της περιοχής και εκτείνεται σε μήκος περίπου ~30km. Ωστόσο η ζώνη διάρρηξης, η οποία είναι σε συμφωνία με το αποτέλεσμα Kiratzi (2021) για τα μοντέλα ολίσθησης των δύο σεισμών. Δεν φαίνεται να σχετίζεται με κάποιο από τα γνωστά ρήγματα.

Ο τελευταίος ισχυρός σεισμός στη περιοχή σχετίζεται με το κανονικό ρήγμα του Τυρνάβου (Παπαζάχος και Παπαζάχου, 2003) το οποίο βρίσκεται ΒΑ της πόλης και δεν φαίνεται να έχει δραστηριοποιηθεί στη παρούσα φάση.

Από παρατηρήσεις πεδίου Ganas et al (2021), Pavlides et al., (2021) προκύπτει ότι η ακολουθία του Μαρτίου 2021, προήλθε από αχαρτογράφητο τυφλό ρήγμα, το οποίο είναι παράλληλο και δυτικότερα από γνωστά ρήγματα. Τα χαρακτηριστικά του ρήγματος της ακολουθίας είναι ακόμη υπό διερεύνηση.

1.2 Κατανομή της Ισχυρής Σεισμικής Κίνησης στη Πλειόσειστη Περιοχή

Στη πόλη της Λάρισας το ΙΤΣΑΚ έχει εγκατεστημένους 2 επιταχυνσιογράφους. Επίσης στη πόλη ο Δήμος Λαρισαίων λειτουργεί δίκτυο οκτώ επιταχυνσιογράφων από τους οποίους οι

δύο είναι τηλεμετρικά συνδεδεμένοι (τηλεφωνική τηλεμετρία) για τη λήψη των δεδομένων.

Οι επιταχυνσιογράφοι του ΙΤΣΑΚ είναι ο LAR1 τύπου QDR με ανάλυση ψηφιοποιητή 11 bits, ενώ ο LAR4 είναι τύπου GURALP-CMG-5TD EAM με ανάλυση 24 bits. Οι επιταχυνσιογράφοι S4 και S5 του Δήμου είναι GeoSIG ανάλυσης 22 bits και βρίσκονται περιμετρικά της πόλης. Λόγω της εγκατάστασης τους σε σχολεία και των περιοριστικών μέτρων δεν κατέστη δυνατή η συλλογή των δεδομένων από τους λοιπούς σταθμούς.

Εντός του κέντρου της Λάρισας καταγράφηκε μέγιστη εδαφική επιτάχυνση ~10%g στο Νοσοκομείο της Λάρισας.

Εικόνα ΣΕΙΣ3. Χάρτης χωρικής κατανομής των θέσεων των επιταχυνσιογράφων στη πόλη της Λάρισας.

Στο χάρτη τους σχήματος ΣΕΙΣ 3 δίνεται η θέση των τεσσάρων επιταχυνσιογράφων από τους οκτώ εγκατεστημένους στη πόλη της Λάρισας.

Οι αναλύσεις των καταγραφών από του τέσσερις επιταχυνσιογράφους για τους δύο ισχυρότερους σεισμούς δίνονται στα Σχήματα 4 ÷ 11, ενώ τα αποτελέσματα και η επικεντρική απόσταση, R, δίνονται στους αντίστοιχους πίνακες (βλέπε πλήρες άρθρο).

Στα Σχήματα 12 και 13 δίνονται για λόγους σύγκρισης τα φάσματα επιταχύνσεων των οριζοντίων συνιστωσών για απόσβεση 5% της κρίσιμης.

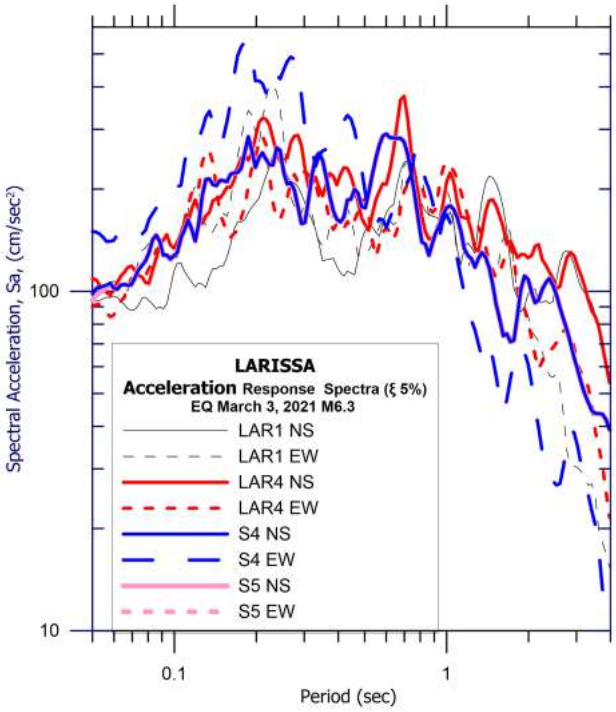
Στο σεισμό της 3ης Μαρτίου, τα φάσματα απόκρισης παρουσίασαν σχετικά επιταχύνσεις, $S_a \geq 200 cm/sec^2$ για μεγάλος εύρος ιδιοπεριόδων, $0.1sec \leq T \leq 1.5sec$.

Αντίθετα κατά το σεισμό της 4 Μαρτίου τα φάσματα απόκρισης παρουσίασαν αρκετά χαμηλότερες τιμές $S_a \leq 200 cm/sec^2$ για όλο το φάσμα των ιδιοπεριόδων.

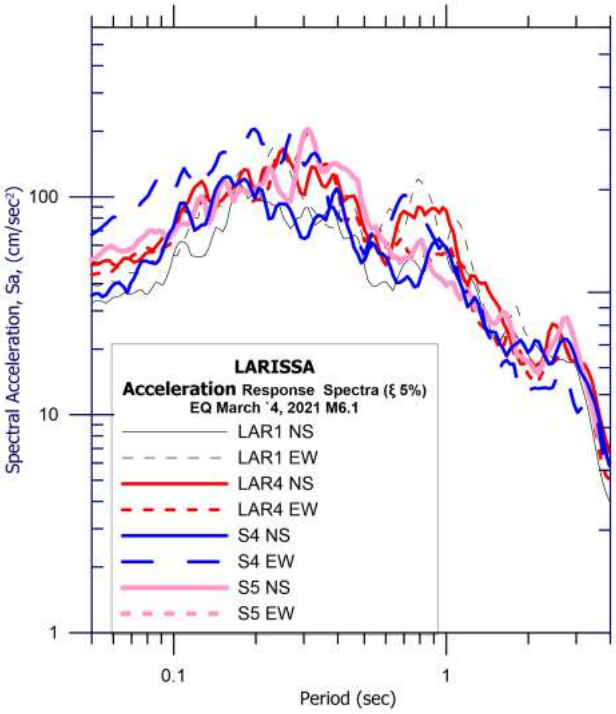
Μια τέτοια διαφορά είναι ποιοτικά αναμενόμενη δεδομένου ότι ο δεύτερος σεισμός είχε μικρότερο μέγεθος και μεγαλύτερη επικεντρική απόσταση από τους σταθμούς καταγραφής.

1.3 Χάρτες Κατανομής της Σεισμικής Κίνησης

Οι χάρτες της κατανομής ισχυρής σεισμικής δόνησης είναι πρωταρχικής σημασίας για την ταχεία αξιολόγηση των αναμενόμενων ζημιών και της έκθεσης του πληθυσμού σε κινδύνους καταστροφών για στις αρχές πολιτικής προστασίας. Για το σκοπό αυτό, το λογισμικό ShakeMap, που αναπτύχθηκε από τα τέλη της δεκαετίας του 1990 από την Αμερικανική Γεωλογική Έρευνα (USGS), αποδείχθηκε πολύ αποτελεσματικό και υιοθετήθηκε από διάφορους φορείς λειτουργίας δικτύων σεισμογράφων/επιταχυνσιογράφων παγκοσμίως.



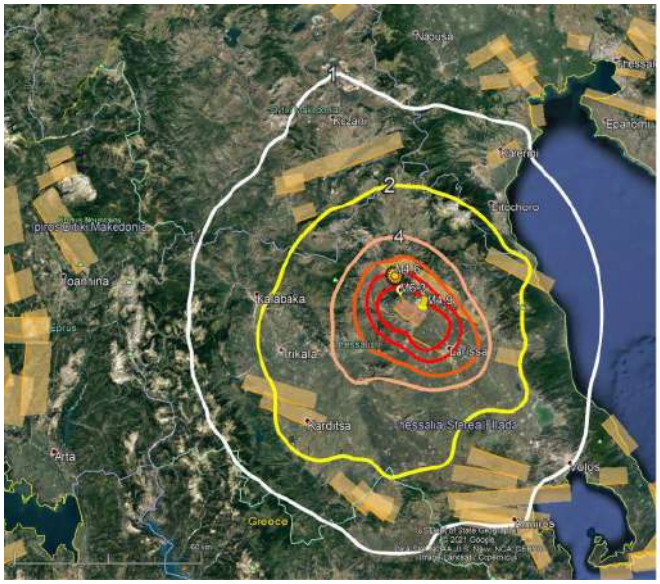
Εικόνα ΣΕΙΣ12. Σύγκριση των φασμάτων απόκρισης των οριζοντίων συνιστωσών των καταγραφών από τους επιταχυνσιογράφους μέσα στο πολεοδομικό συγκρότημα της Λάρισας για το σεισμό Μ6.3 της 3ης. Μαρτίου 2021. Οι συνεχείς γραμμές αντιστοιχούν στις συνιστώσες NS ενώ οι διακεκομμένες για τις συνιστώσες EW.



Εικόνα ΣΕΙΣ13. Σύγκριση των φασμάτων απόκρισης των οριζοντίων συνιστωσών των καταγραφών από τους επιταχυνσιογράφους μέσα στο πολεοδομικό συγκρότημα της Λάρισας για το σεισμό Μ6.1 της 4ης. Μαρτίου 2021. Οι συνεχείς γραμμές αντιστοιχούν στις συνιστώσες NS ενώ οι διακεκομμένες για τις συνιστώσες EW. Η κλίμακα των φασματικών επιταχύνσεων είναι ίδια με το προηγούμενο σχήμα για λόγους σύγκρισης.

Το ShakeMap (Wald et al., 1999) είναι ένα λογισμικό για την εκτίμηση της κίνησης εδάφους, το οποίο χρησιμοποιεί καταγεγραμμένα δεδομένα και τα συνδυάζει με σεισμολογικά και γεωτεχνικά δεδομένα για την δημιουργία χαρτών κίνησης εδάφους. Τα μοντέλα πρόβλεψης σεισμικής δόνησης εδάφους(GMPEs ή GMMs) χρησιμοποιούνται για την όσο το δυνατόν ακριβέστερης εκτίμηση αυτής όπου δεν υπάρχουν διαθέσιμες καταγραφές. Η επίδραση των τοπικών συνθηκών γίνεται με χρήση της ενίσχυσης στην εξεταζόμενη θέση, με βάση την μέση ταχύτητα διάδοσης των εγκαρσίων κυμάτων (S-waves) στα ανώτερα 30 m (V_S30).

Λεπτομέρειες σχετικά με τη μεθοδολογία των Shakemaps παρέχονται από τους Worden et al. (2017). Τα μεταγενέστερα εργαλεία έχουν αναπτυχθεί για να παρέχουν εκτιμήσεις απωλειών στον πληθυσμό και βλαβών στις υποδομές που εκτίθενται σε κίνδυνο και υπολογίζουν τις οικονομικές απώλειες στις περιοχές που επηρεάζονται από το σεισμικό συμβάν (π.χ. Earle et al., 2009).



Εικόνα ΣΕΙΣ14. Χάρτης αισθητότητας με παράμετρο τη μέγιστη επιτάχυνση (σε %g). Οι καμπύλες είναι μεταξύ 2%g-10%g ενώ η τελευταία είναι για 1%g.

Στο χάρτη του σχήματος ΣΕΙΣ 14 δίνεται η χωρική κατανομή των εδαφικών επιταχύνσεων όπως προέκυψαν από τη χρήση των δεδομένων του δικτύου επιταχυνσιογράφων του ΙΤΣΑΚ. Δίνονται επίσης και τα γνωστά ρήγματα στη περιοχή (Pavlides et al., 2010).

Οι καμπύλες ίσων τιμών επιταχύνσεων φαίνεται ότι έχουν επιμήκυνση κατά τη διεύθυνση ΒΔ-ΝΑ, συμπίπτοντας δηλαδή με τη διεύθυνση της ρηξιγενούς ζώνη όπως φαίνεται από το σχήμα ΣΧΗΜ2.

1.4 Συμπεράσματα

Η σεισμική ακολουθία της ΒΑ. Θεσσαλίας με δύο σεισμούς περίπου ιδίου μεγέθους, Μ6.3 και Μ6.1 προκλήθηκε από κανονικές διαρρήξεις με διεύθυνση ΒΔ-ΝΑ.

Η μέγιστη εδαφική επιτάχυνση στη πόλη της Λάρισας ήταν ~140 cm/sec^2, με επιτάχυνση σχεδιασμού κατά τον ΕΑΚ2000, a_g:24%g.

Τα φάσματα απόκρισης και των δύο σεισμών διαφοροποιούνται αρκετά στις 4 θέσεις της πόλης της Λάρισας παρά το γεγονός ότι έχουν παρόμοιες επικεντρικές αποστάσεις (~25km).

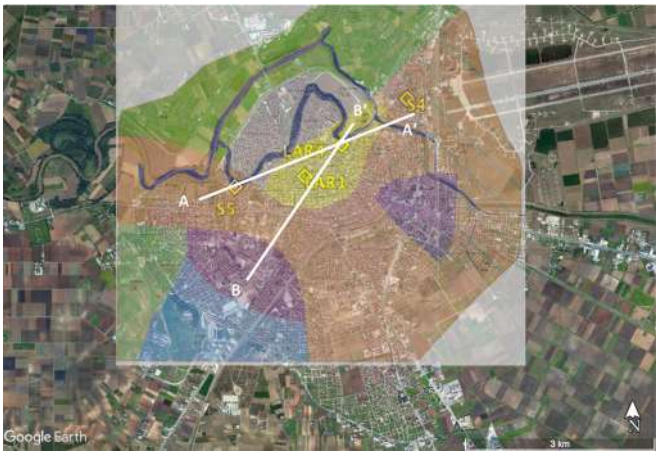
Η παρατήρηση αυτή αναδεικνύει το ρόλο των διαφορετικών τοπικών εδαφικών συνθηκών στις θέσεις των επιταχυνσιογράφων που διαμόρφωσαν ανάλογα τη σεισμική δόνηση μέσα στο πολεοδομικό συγκρότημα. Επιπλέον, η σημαντική διαφοροποίηση στις δύο οριζόντιες συνιστώσες των φασμάτων απόκρισης του ίδιου σταθμού, υποδεικνύει 2Δ ή και 3Δ επίδραση, γεγονός που μπορεί να διερευνηθεί με σχετική μοντελοποίηση της δυναμικής απόκρισης των επιφανειακών γεωλογικών σχηματισμών. Η υφιστάμενη μικροζωνική μελέτη στην πόλη της Λάρισας μπορεί να συμβάλει σε μια τέτοια διερεύνηση καθώς επίσης να τεκμηριωθεί ανάλογα.

2. ΓΕΩΛΟΓΙΚΑ - ΓΕΩΤΕΧΝΙΚΑ ΣΤΟΙΧΕΙΑ ΚΑΙ ΕΔΑΦΙΚΕΣ ΑΣΤΟΧΙΕΣ

2.1 Πολεοδομικό συγκρότημα Λάρισας – τεκμηρίωση θέσεων σταθμών καταγραφής της ισχυρής κίνησης

Η γεωλογία της περιοχής όπου έχει αναπτυχθεί το πολεοδομικό συγκρότημα της Λάρισας χαρακτηρίζεται από αλλουβιακές αποθέσεις (ΙΓΜΕ Φύλλο Λάρισα 1:50.000) και ειδικότερα ανοικτότεφρα έως καστανότεφρα ασύνδετα υλικά από αργίλους, άμμους, κροκαλολατύπες και ποταμοχειμαρολιμναία υλικά που αποτέθηκαν στη λεκάνη της Λάρισας.

Στην εικόνα ΓΕΩ1 αποτυπώνονται οι θέσεις των επιταχυνσιογράφων LAR1, LAR4, S4 και S5 στο πολεοδομικό συγκρότημα της Λάρισας. Στο ίδιο σχήμα υπερτίθεται ο γεωτεχνικός χάρτης που προέκυψε από την επεξεργασία γεωτεχνικών δεδομένων στο πλαίσιο εκπόνησης μικροζωνικής μελέτης της πόλης (ΑΠΘ-Νομαρχία Λάρισας, 1995; ΤΕΕ-ΤΚΔΘ, 2000) με τις διευθύνσεις των γεωτεχνικών τομών που διέρχονται από τους σταθμούς καταγραφής της σεισμικής κίνησης. Στην εικόνα ΓΕΩ2 δίνεται η γεωτεχνική τομή Α-Α’ που διέρχεται από τους σταθμούς S5, LAR4 και S4 καθώς και η τομή Β-Β’ διερχόμενη από τους σταθμούς LAR1 και LAR4.

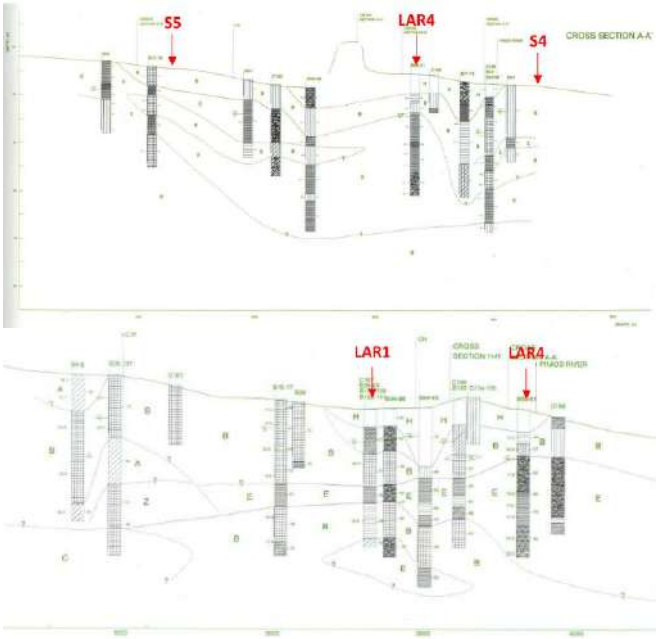


Εικόνα ΓΕΩ1. Θέσεις των επιταχυνσιογράφων στο πολεοδομικό συγκρότημα της Λάρισας σε σχέση με το γεωτεχνικό χάρτη που προέκυψε από την επεξεργασία γεωτεχνικών δεδομένων στο πλαίσιο εκπόνησης της μικροζωνικής μελέτης της πόλης (ΑΠΘ-Νομαρχία Λάρισας, 1995; ΤΕΕ-ΤΚΔΘ, 2000) με τις θέσεις των τομών που διέρχονται από τους σταθμούς καταγραφής της σεισμικής κίνησης.

Οι σταθμοί LAR1 και LAR4, πρακτικά βρίσκονται εντός της ίδιας γεωτεχνικής ζώνης στην οποία συναντώνται επιφανειακά τεχνητές επιχωματώσεις (Η), εξαιρετικά ετερογενείς και γενικά πολύ χαμηλής αντοχής, σε βάθη που κυμαίνονται μεταξύ 2-10m (Εικ. ΓΕΩ1). Σε μεγαλύτερο βάθος (Εικ. ΓΕΩ2, τομή Β-Β’) παρατηρούνται εναλλαγές αργίλων μέσης και κατά θέσεις υψηλής πλαστικότητας, με κυμαινόμενο ποσοστό ιλύος και με σημαντικές διαφορές στις μηχανικές ιδιότητες (Β) και άμμων με ιλύ ή/και άργιλο με κυμαινόμενο ποσοστό ιλύος ή/και αργίλου έως λεπτόκοκκες ιλυώδεις άμμοι με μικρή έως μηδενική πλαστικότητα σε χαλαρή σύσταση (Ε).

Ομοίως οι σταθμοί S5 και S4 (Εικ. ΓΕΩ1 και ΓΕΩ2) ανήκουν στην ίδια γεωτεχνική ζώνη στην οποία συναντώνται επιφανειακά αργιλικοί σχηματισμοί (Β) πάχους ως 8m. Στη συνέχεια

και μέχρι το βάθος των 40m περίπου, στο μεν δυτικό τμήμα (περιοχή σταθμού S5) επικρατούν αμμοϊλυώδεις σχηματισμοί (Ε) με ενστρώσεις αργίλου (Σχηματισμός Β), στο δε ανατολικό τμήμα (περιοχή σταθμού S4) επικρατούν αργιλικοί σχηματισμοί (Β) με ενστρώσεις αμμοϊλυωδών εδαφών (Ε).



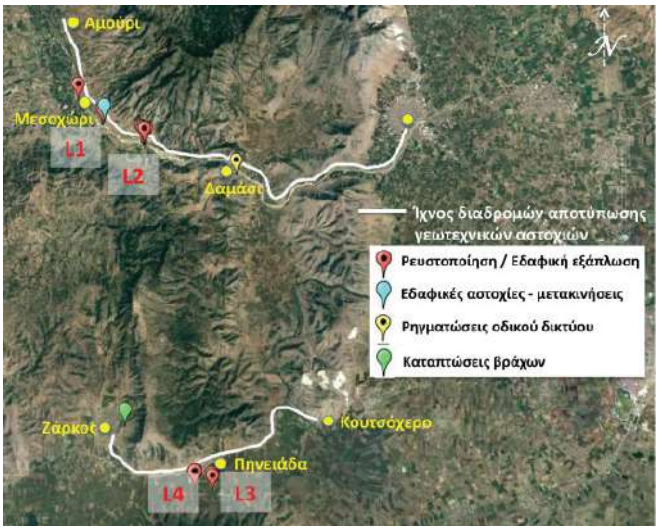
Εικόνα ΓΕΩ2. Γεωτεχνικές τομές: Α-Α' διερχόμενη από τους σταθμούς S5, LAR4 και S4 (πάνω) και Β-Β' που διέρχεται από τους σταθμούς LAR1 και LAR4 (ΑΠΘ-Νομαρχία Λάρισας, 1995; ΤΕΕ-ΤΚΔΘ, 2000)

Από τη συσχέτιση των παραμέτρων των βασικών σχηματισμών ανά ζώνη με μετρήσεις Cross-hole καθώς και άλλων γεωφυσικών μεθόδων διασκόπησης, αλλά και συσχετίσεων με τιμές NSPT, εκτιμάται ότι η μέση ταχύτητα διάδοσης των διατμητικών κυμάτων στα πρώτα 30m, $V_{S,30}$, κυμαίνεται περί τα 290 m/s και 300 m/s στις θέσεις των σταθμών LAR4 και LAR1 αντίστοιχα, περί τα 310 m/s στη θέση του σταθμού S5 και περί τα 260m/s στη θέση S4. Σύμφωνα με τις παραπάνω τιμές $V_{S,30}$, όλοι οι σταθμοί καταγραφής της ισχυρής κίνησης κατατάσσονται στην κατηγορία εδάφους C σύμφωνα με τον EC8.

2.2 Πλειόσειστη περιοχή – Αστοχίες γεωτεχνικού χαρακτήρα

Το ενδιαφέρον αναφορικά με την αποτύπωση των γεωτεχνικών αστοχιών επικεντρώθηκε σε δύο (2) διαδρομές. Η 1η διαδρομή πραγματοποιήθηκε κατά μήκος του Τηταρήσιου ποταμού ο οποίος βρίσκεται στο νότιο τμήμα της πλειόσειστης περιοχής και συμπεριέλαβε τον Τύρναβο και τα χωριά: Δαμάσι – Μεσοχώρι – Αμούρι. Η 2η διαδρομή χωροθετείται ακόμη πιο νότια κατά μήκος του ποταμού Πηνειού και περιέλαβε τα χωριά: Ζάρκος – Πηνειάδα – Κουτσόχερο. Οι διαδρομές παρουσιάζονται στην εικόνα ΓΕΩ3.

Στην παρούσα ενότητα παρουσιάζονται συνοπτικά οι τύποι εδαφικής αστοχίας οι οποίοι επισημάνθηκαν κατά την τεχνική επίσκεψη της 6/3/2021. Ο βασικός τύπος εδαφικής αστοχίας που καταγράφηκε αφορούσε σε φαινόμενα εκτεταμένης ρευστοποίησης και των εξ αυτής δευτερογενών επαγόμενων φαινομένων, όπως η πλευρική εξάπλωση. Ιδιαίτερο ενδιαφέρον παρουσίασαν επίσης και ειδικότερα θέματα που εντοπίστηκαν όπως η περίπτωση εδαφικής αστοχίας με τη μορφή μεγάλου μήκους εδαφικής ρωγμής στα όρια της ευρύτερης κοίτης του ποταμού Τηταρήσιου. Η παρουσίαση των εν λόγω αστοχιών δεν εξαντλούν το αντικείμενο των εδαφικών αστοχιών, το οποίο είναι χωρικά πιο εκτεταμένο από την περιοχή αναφοράς, αλλά αποτελούν σοβαρή ένδειξη του τύπου των φαινομένων που επικράτησαν στην περιοχή με βάση τις γεωλογικές, τοπογραφικές, γεωμορφολογικές, υδρογεωλογικές και γεωτεχνικές συνθήκες.



Εικόνα ΓΕΩ3. Ίχνος διαδρομής αποτύπωσης γεωτεχνικών αστοχιών και θέσεις καταγραφής τους

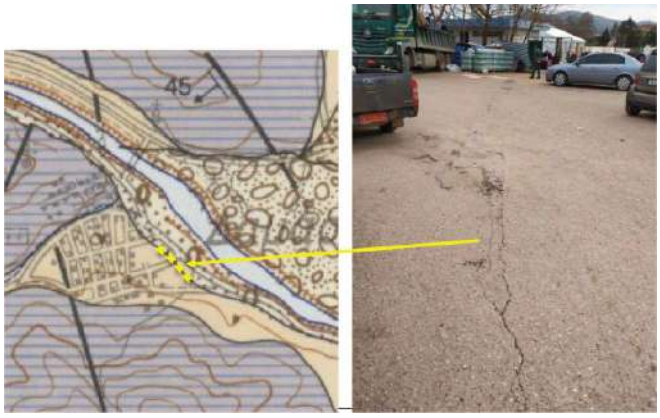
2.2.1. Διαδρομή 1: Τύρναβος - Δαμάσι - Μεσοχώρι – Αμούρι

Η 1η διαδρομή ακολουθεί τη διεύθυνση Α-Δ. Το χωριό Δαμάσι είναι ένα από τα χωριά που βρίσκονται στην επικεντρική περιοχή και τα οποία υπέστησαν σημαντικές βλάβες στο κτηριακό τους απόθεμα και κυρίως στα λιθόκτιστα και πλινθόκτιστα κτήρια. Από γεωτεχνικής πλευράς, ενδιαφέρον παρουσιάζει η παρατήρηση ότι οι κτηριακές βλάβες παρουσιάζονται μειωμένες στην περιοχή που βρίσκεται στις υπώρειες του ορεινού ανάγλυφου στα νότια του χωριού (Εικ. ΓΕΩ4), γεγονός που πιθανόν να ερμηνεύεται από την καλύτερη μηχανική συμπεριφορά που παρουσιάζουν οι εδαφικές στρώσεις από πλευρικά κορήματα αργιλοαμμώδους έως αργιλοαμμοχαλικώδους σύστασης ή με συμπεριφορά μαλακού βράχου/σκληρού εδάφους λόγω της χαμηλής συγκόλλησης των εδαφικών υλικών, σε σχέση με τις ποτάμιες αναβαθμίδες της ευρείας κοίτης του Τηταρήσιου ή και του αλλουβιακού μανδύα.

Εικόνα ΓΕΩ4. Εντοπισμός οικιστικής ζώνης Δαμασίου η οποία εμφάνισε λιγότερες βλάβες δομικού τύπου.

Επίσης, ενδιαφέρον παρουσιάζει και η ύπαρξη εδαφικών ρωγμών μικρού εύρους (1-2cm ή και μικρότερου) επί του οδικού δικτύου στην περιοχή της εισόδου του χωριού οι οποίες είναι περίπου παράλληλες προς την κοίτη του παρακείμενου ποταμού Τηταρήσιου (Εικ. ΓΕΩ5), στο όριο μεταξύ ποτάμιων αναβαθμίδων (αδρομερή υλικά με κροκάλες και λατύπες) και πλευρικών κορημάτων (ελαφρώς συγκολλημένα κροκαλοπαγή ή λατυποπαγή αργιλοαμμοχαλικώδους σύστασης) ή ποτάμιων αναβαθμίδων και ελουβιακού μανδύα (μη-συνεκτικά

χονδρόκοκκα υλικά προερχόμενα από το υποκείμενο βραχώδες υπόβαθρο) σύμφωνα με το γεωλογικό χάρτη του ΙΓΜΕ (Φύλλο Φαρκαδών, Κλ. 1:50.000).



Εικόνα ΓΕΩ5. Ρωγμές μικρού εύρους (1-2cm ή και μικρότερου) που καταγράφηκαν επί του οδικού δικτύου στην περιοχή της εισόδου του χωριού Δαμάσι σε διάταξη παράλληλη προς την κοίτη του παρακείμενου ποταμού Τηταρήσιου. Η θέση των ρωγμών φαίνεται να συμπίπτει με το όριο μεταξύ ποτάμιων αναβαθμίδων και πλευρικών κορημάτων ή ποτάμιων αναβαθμίδων και ελουβιακού μανδύα σύμφωνα με το γεωλογικό χάρτη του ΙΓΜΕ (Φύλλο Φαρκαδών, Κλ. 1:50.000) (Συν/νες θέσης φωτογραφίας: N39°42'41.81", E22°11'25.15")

Τέλος, στη γέφυρα μέσω της οποίας εισέρχεται κάποιος στο Δαμάσι, κινούμενος στην επαρχιακή οδό με κατεύθυνση από Τύρναβο προς Ελασσόνα, πέραν των μετακινήσεων που διαπιστώθηκαν μεταξύ βάθρων και ακροβάθρων, οι οποίες εκτιμώνται της τάξης των 10cm (ενδεχομένως και ελαφρώς μεγαλύτερες κατά τη διάρκεια τη σεισμικής δόνησης) με βάση την εικόνα των εξολκευμένων σωλήνων μεταξύ ακροβάθρου και διπλανού βάθρου, εντοπίστηκαν και φαινόμενα πλευρικής εξάπλωσης σε μικρό βαθμό κατά μήκος της κοίτης του ποταμού Τηταρήσιου (Εικ. ΓΕΩ6)

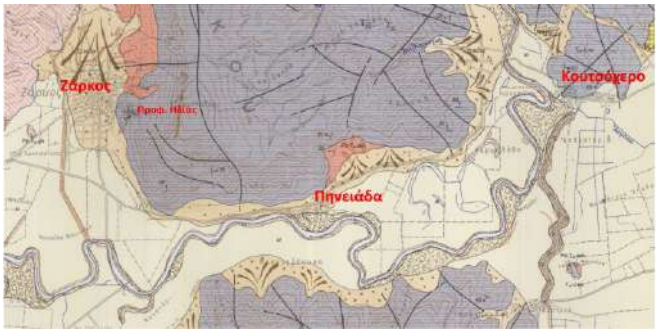
Στη συνέχεια, κατά μήκος της επαρχιακής οδού Τύρναβου – Ελασσόνας που ενώνει τα χωριά Δαμάσι και Μεσοχώρι επιλέχθηκαν 2 χαρακτηριστικά σημεία της ευρείας κοίτης του ποταμού όπου εντοπίσθηκαν αρκετά έντονα φαινόμενα ρευστοποίησης με ανάπτυξη ρωγμών κατά μήκος της κοίτης του ποταμού, προφανής εκδήλωση του επαγόμενου φαινόμενου της πλευρικής εξάπλωσης. Αναλυτικότερη αναφορά γίνεται στην παράγραφο 2.2.3.

Στα χωριά Μεσοχώρι και Αμούρι δεν εντοπίστηκαν ιδιαίτερα φαινόμενα εδαφικών αστοχιών ή έντονα διαφοροποιημένης σεισμικής απόκρισης των υποκείμενων εδαφικών σχηματισμών με βάση την οπτική παρατήρηση ποιοτικού χαρακτήρα επί της επιφάνειας του εδάφους και το είδος των βλαβών στα κτήρια.

2.2.2 Διαδρομή 2: Ζάρκος – Πηνειάδα - Κουτσόχερο

Η 2η διαδρομή χωροθετείται νοτιότερα της 1ης κατά 12 έως 15 Km και αναπτύσσεται επίσης κατά τη διεύθυνση Α-Δ, όπως και η 1η διαδρομή (Εικ. ΓΕΩ3). Το χωριό Ζάρκος βρίσκεται βόρεια του οδικού άξονα Ε.Ο. Λάρισα – Τρίκαλα σε απόσταση περίπου 1Km στην άκρη μιας κοιλάδας η οποία αποσφηνώνεται λίγο βορειότερα του χωριού, ενώ ανατολικά, βόρεια και δυτικά αυτού περικλείεται από ορεινούς όγκους (Εικ. ΓΕΩ7). Οι ανατολικοί ορεινοί όγκοι συνίστανται από μάρμαρα και σχιστόλιθους, ενώ ο δυτικός και βόρειος ορεινός όγκος δομείται από γνεύσιους και γνευσιοσχιστόλιθους. Στην περιοχή ανάπτυξης του χωριού (Ζάρκος) επικρατούν σύμφωνα με τον γεωλογικό χάρτη του ΙΓΜΕ (Φύλλο Φαρκαδών, Κλ. 1:50.000) ελαφρώς συγκολλημένα πλευρικά κορήματα ή και κώνοι κορημάτων τα οποία σύμφωνα με την επιτόπου παρατήρηση είναι αργιλοαμμώδους ή και αργιλοαμμοχαλικώδους σύστασης με κροκάλες και λατύπες. Πρόκειται για εδάφη πολύ στιφρά / σκληρά και με καλές μηχανικές ιδιότητες, χωρίς ιδιαίτερα προβλήματα για τη θεμελίωση κατασκευών.

Εικόνα ΓΕΩ6. Φαινόμενα πλευρικής εξάπλωσης σε μικρό βαθμό κατά μήκος της κοίτης του ποταμού Τηταρήσιου (θέση κοντά στην γέφυρα εισόδου στο χωριό Δαμάσι, κινούμενος στην επαρχιακή οδό με κατεύθυνση από Τύρναβο προς Ελασσόνα) (Συν/νες θέσης φωτογραφίας: N39°42'58.46", E22°11'18.73")



Εικόνα ΓΕΩ7. Απόσπασμα χάρτη ΙΓΜΕ (Φύλλο Φαρκαδών Κλ. 1:50.000) στο οποίο έχουν σημειωθεί τα χωριά που συμπεριέλαβε η 2η διαδρομή αποτύπωσης των εδαφικών αστοχιών.

Από τους ανατολικούς ορεινούς όγκους αποσπάσθηκαν βραχώδη τεμάχη τα οποία κύλησαν σε τοπογραφικά χαμηλότερα σημεία, σταματώντας ωστόσο σε μεγάλη απόσταση από τις οικίες και οποιαδήποτε άλλη κατασκευή του χωριού και χωρίς να προκληθεί καμία βλάβη. Ενδεικτικά παρατίθενται εικόνες από τους ανατολικούς ορεινούς όγκους από τους οποίους αποσπάσθηκαν βραχοτεμάχη και κύλησαν κατάντι, καθώς επίσης ενδεικτικό μέγεθος βραχοτέμαχους (Εικ. ΓΕΩ8). Στα ανατολικά, μεταξύ του ορεινού όγκου και του χωριού υφίσταται λόφος ύψους περί τα 60m και με συνολική υψομετρική δια-

φορά από το άκρο του χωριού περί τα 100m, στην κορυφή του οποίου υπάρχει παρεκκλήσι του προφήτη Ηλία. Παρά το γεγονός ότι υπάρχει εμφανής τοπογραφική έξαρση, το πέτρινο παρεκκλήσι δεν παρουσίασε καμία βλάβη (Εικ. ΓΕΩ9).

Εικόνα ΓΕΩ8. Απόσπαση βραχωδών τεμάχων από ορεινούς όγκους ανατολικά του χωριού Ζάρκος (Συν/νες θέσης φωτογραφίας: N39°36'24.64"; E22°7'57.95")

Εικόνα ΓΕΩ9. Παρεκκλήσι του προφήτη Ηλία το οποίο βρίσκεται σε λόφος ύψους περί τα 60m ανατολικά μεταξύ του ορεινού όγκου και του χωριού Ζάρκος: Παρά την έντονη τοπογραφική έξαρση στη θέση, το πέτρινο παρεκκλήσι δεν παρουσίασε βλάβες (Συν/νες θέσης φωτογραφίας: N39°36'21.48"; E22°7'50.81")

Το επόμενο χωριό είναι η Πηνειάδα η οποία βόρεια οριοθετείται από την Ε.Ο Λάρισας – Τρικάλων και έναν ορεινό όγκο από μάρμαρα (κυρίως) και δευτερευόντως από σχιστολίθους και νότια από τον ποταμό Πηνειό (Εικ. ΓΕΩ7). Το χωριό έχει αναπτυχθεί, σύμφωνα με τον γεωλογικό χάρτη του ΙΓΜΕ (Φύλλο Φαρκαδών, Κλ. 1:50.000), κυρίως επί ελαφρώς συγκολλημένων πλευρικών κορημάτων ή κώνων κορημάτων τα οποία σύμφωνα με την επιτόπου παρατήρηση είναι αργιλοαμμώδους σύστασης ή και αργιλοαμμοχαλικώδους σύστασης με κροκάλες και λατύπες. Πρόκειται για εδάφη πολύ στιφρά έως σκληρά με καλές μηχανικές ιδιότητες, χωρίς ιδιαίτερα προβλήματα για τη θεμελίωση κατασκευών, γεγονός το οποίο συνάδει με την πληροφορία ότι οι βλάβες στο κτηριακό απόθεμα ήταν πολύ περιορισμένες. Νοτιότερα του χωριού επικρατούν ποτάμιες αναβαθμίδες και κυρίως μαλακά / χαλαρά αμμοϊλυώδη έως αργιλοϊλυώδη υλικά χαμηλής εν γένει πλαστικότητας και με υψηλό υπόγειο υδάτινο ορίζοντα τα οποία σήμερα είναι εύφορες καλλιεργήσιμες εκτάσεις και αποτελούν μέρος της ευρύτερης κοίτης του ποταμού ή πρόκειται για παλαιότερες θέσεις διέλευσης του ποταμού. Στις περιοχές αυτές υπήρξαν ιδιαίτερα έντονα προβλήματα εκτεταμένων ρευστοποιήσεων, για τα οποία γίνεται ιδιαίτερη μνεία στην παράγραφο 2.2.3. Τέλος, το Κουτσόχερο είναι το τελευταίο χωριό της 2ης διαδρομής και στο οποίο δεν επισημάνθηκαν ιδιαίτερα φαινόμενα εδαφικής αστοχίας.

2.2.3 Ρευστοποιήσεις – Πλευρική εξάπλωση – Εδαφικές Ρωγμές

Τα φαινόμενα τα οποία προσελκύουν το ιδιαίτερο γεωτεχνικό ενδιαφέρον είναι κυρίως οι ρευστοποιήσεις στις ευρείες κοίτες των ποταμών Τητηρήσιου και Πηνειού, οι οποίες είναι κατά περίπτωση ιδιαίτερα εκτεταμένες, καθώς επίσης και μια πεταλοειδής εδαφική ρωγμή στην παραποτάμια περιοχή του Τητηρήσιου ποταμού και σε απόσταση περίπου 1,5Km από το Μεσοχώρι με κατεύθυνση προς Δαμάσι η οποία παρουσιάζει ιδιαίτερα χαρακτηριστικά σε σχέση με τις ρωγμές / εδαφικές αστοχίες λόγω πλευρικής εξάπλωσης.

- *Θέσεις κατά μήκος του Τητηρήσιου ποταμού μεταξύ Δαμασίου και Μεσοχωρίου*

Στην αμμώδη ευρεία κοίτη του Τητηρήσιου ποταμού διαπιστώθηκαν σε 2 θέσεις από μικρής έως αρκετά σημαντικής έκτασης ρευστοποιήσεις, καθώς επίσης και πλευρικές εξαπλώσεις με εμφάνιση ρωγμών μικρού εύρους (χιλιοστών έως λίγα εκατοστά). Λόγω της αμμώδους / αμμοχαλικώδους σύστασης της επιφανειακής στρώσης, οι ρωγμές λόγω πλευρικής εξάπλωσης, κατά περίπτωση διακόπτονται ή και «σβήνονται» και η μέτρηση του εύρους τους δεν θεωρείται ασφαλής μέτρηση, αλλά εξακολουθεί να είναι ενδεικτική της ύπαρξης του φαινομένου. Το υλικό που «αναδύθηκε» στην ελεύθερη επιφάνεια του εδάφους είναι καστανόφαιου χρώματος και εκτιμάται ότι είναι ιλυοαμμώδους σύστασης με μικρή ή και ανύπαρκτη πλαστικότητα με βάση την ποιοτική μακροσκοπική αξιολόγηση. Χαρακτηριστικές φωτογραφίες από την εκδήλωση του φαινομένου της ρευστοποίησης στις δύο θέσεις δίνονται στα Εικ. ΓΕΩ10 (θέση L1) και ΓΕΩ11 (θέση L2).

Εικόνα ΓΕΩ10. Χαρακτηριστικές αποτυπώσεις φαινομένου ρευστοποίησης και επαγόμενης πλευρικής εξάπλωσης στην ευρεία κοίτη του Τητηρήσιου ποταμού (Θέση L1) (Συν/νες θέσης φωτογραφίας: N39°44'5.50"; E22°6'52.89" (αριστερά πάνω), N39°44'4.88"; E22°6'53.81" (αριστερά κάτω) N39°44'5.45"; E22°6'51.51" (δεξιά))

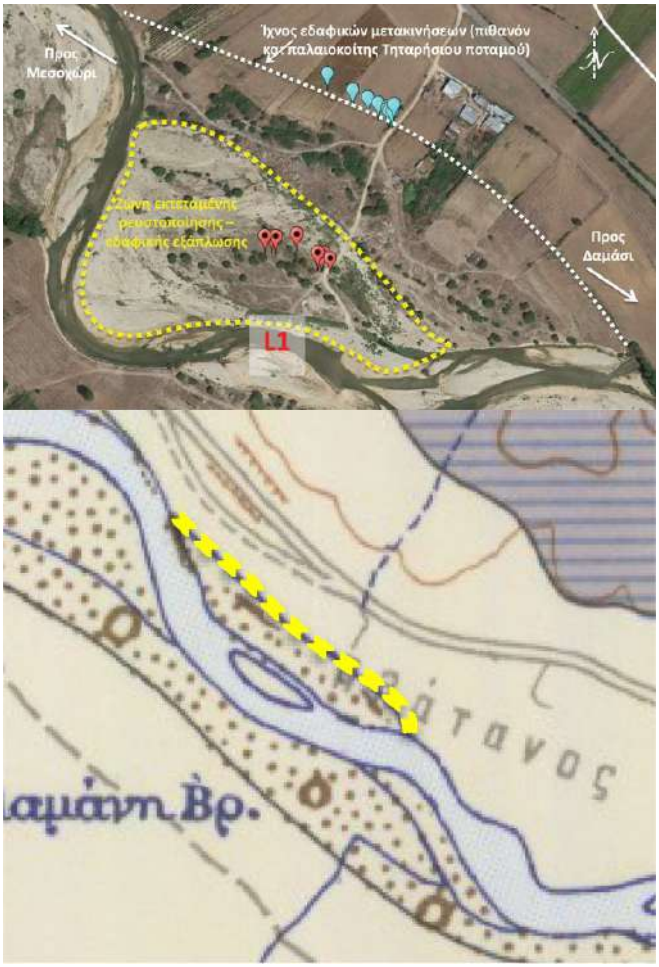
Εικόνα ΓΕΩ11. Χαρακτηριστικές αποτυπώσεις φαινομένου ρευστοποίησης και επαγόμενης πλευρικής εξάπλωσης στην ευρεία κοίτη του Τηταρήσιου ποταμού (Θέση L2) (Συν/νες θέσης φωτογραφίας: N39°43'31.74"; E22°8'20.28" (αριστερά πάνω), N39°43'31.43"; E22°8'19.16" (αριστερά κάτω) N39°43'32.83"; E22°8'16.60" (δεξιά))

Στην ευρύτερη περιοχή όπου παρατηρήθηκαν φαινόμενα ρευστοποίησης (Εικ. ΓΕΩ10, θέση L1), ιδιαίτερο ενδιαφέρον παρουσιάζει η εδαφική ρωγμή πεταλοειδούς σχήματος η οποία είναι σημαντικά μεγαλύτερου μήκους και εντονότερη ως προς τη σχετική οριζόντια και κατακόρυφη μετακίνηση των δύο μερών από τις υπόλοιπες εδαφικές ρωγμές λόγω πλευρικής εξάπλωσης. Η υπόψη εδαφική αστοχία, με βάση τη γεωμορφολογία και τη δορυφορική παρατήρηση μέσω google earth φαίνεται να ακολουθεί το όριο μεταξύ των φερτών αλλουβιακών υλικών της ευρείας κοίτης (ιλυοαμμώδους – αμμώδους ή και αμμοχαλικώδους σύστασης) και των υλικών αποσάθρωσης του ανάντη ευρισκόμενου ορεινού όγκου από μάρμαρα και κροκαλοπαγή – λατυποπαγή χαμηλής διαγένεσης (Εικ. ΓΕΩ12). Η παραπάνω παρατήρηση ενισχύεται και από τη συσχέτιση της αποτύπωσης της εν λόγω εδαφικής ρωγμής μεταξύ της δορυφορικής εικόνας (άσπρη διακεκομμένη γραμμή στην εικόνα ΓΕΩ12 – άνω) και του σχετικού αποσπάσματος του γεωλογικού χάρτη του ΙΓΜΕ (κίτρινη διακεκομμένη γραμμή στην εικόνα ΓΕΩ12 – κάτω).

Συγκεκριμένα η οριζόντια μετακίνηση δείχνει να έχει λάβει χώρα με κατεύθυνση ΝΝΔ-ΝΔ με εύρος κυμαινόμενο από 3 έως 15cm ενώ η κατακόρυφη βύθιση στα σημεία που μετρήθηκε κυμάνθηκε από 5 έως 30cm. Με βάση τα παραπάνω πιθανολογείται ότι πρόκειται για μετακίνηση η οποία δεν σχετίζεται άμεσα με την κίνηση του σεισμικού ρήγματος, ούτε όμως πρόκειται και για πλευρική εξάπλωση λόγω ρευστοποίησης. Μάλλον ερμηνεύεται ως προϋπάρχουσα επαφή, μεταξύ γηγενών εδαφικών σχηματισμών προερχόμενων από τους ανάντη ευρισκόμενους ορεινούς όγκους και ορίου παλαιότερης κοίτης ή της ευρείας κοίτης του ποταμού, η οποία διευρύνθηκε λόγω της σεισμικής διέγερσης και πιθανής απώλειας στήριξης από τα κατάντη αμμώδη υλικά που μετακινήθηκαν λόγω πλευρικής εξάπλωσης προς την υφιστάμενη κοίτη του ποταμού. Οι φωτογραφίες (Εικ. ΓΕΩ13) αποτυπώνουν τη μορφή και τις σχετικές μετακινήσεις της υπόψη εδαφικής αστοχίας, ενώ από αντιπαραβολή δορυφορικών λήψεων σε διαφορετικές χρονικές στιγμές της ίδιας περιοχής μέσω του google earth προκύπτει ότι υπάρχουν έντονες αλλαγές της ροής του ποταμού μέσα στην ευρεία του κοίτη, γεγονός που ενισχύει την άποψη περί ορίου της ευρείας κοίτης.

- *Θέσεις νοτίως της Πηνειάδας πλησίον του ποταμού Πηνειού*

Παρουσιάζονται 2 θέσεις (L3 και L4, εικ. Χ3) με ιδιαίτερα έντονα και εκτεταμένα φαινόμενα ρευστοποίησης. Σύμφωνα με μαρτυρίες ανθρώπων οι οποίοι εργαζόταν στις υπόψη καλλιεργούμενες εκτάσεις, κατά τη διάρκεια του σεισμού της 3/3/2021 αναδύθηκε υλικό χρώματος γκρι έως σταχτόγκριζο και σε ορισμένα σημεία με τη μορφή πίδακα ύψους έως 50cm. Οι θέσεις που σημειώνονται στην εικόνα ΓΕΩ3 βρίσκονται σε μια περιοχή έντονων μαιανδρισμών του Πηνειού και δεν αποκλείεται καθόλου το ενδεχόμενο να συνιστούν και παλαιοκοίτες του ποταμού. Στην ευρύτερη περιοχή, ιδιαίτερα εύφορη, σύμφωνα με μαρτυρίες των ανθρώπων που την καλλιεργούν, υπάρχουν περί τις 20 υδρογεωτρήσεις που χρησιμοποιούνται για αρδευτικούς λόγους. Σύμφωνα με τους ίδιους η περιοχή αυτή παλαιότερα διέθετε έντονες αρτεσιανές πιέσεις, οι οποίες σήμερα λόγω των αντλήσεων έχουν σημαντικά μειωθεί ή και εκλείψει. Ωστόσο, δεν αποκλείεται να εξακολουθούν να υπάρχουν υπερπιέσεις του επιφανειακού υδροφόρου ορίζοντα, οι οποίες με μικρότερες σεισμικές επιταχύνσεις από τις συνήθως απαιτούμενες να προκάλεσαν τις εκτεταμένες και χωρικά πυκνές ρευστοποιήσεις. Ενδεικτικές εικόνες των ρευστοποιήσεων παρατίθενται στα Εικ. ΓΕΩ14 και ΓΕΩ15.



Εικόνα ΓΕΩ12. Άνω: Αποτύπωση εδαφικής ρωγμής (άσπρη διακεκομμένη γραμμή) μεγάλου μήκους η οποία φαίνεται να ακολουθεί το όριο μεταξύ των φερτών αλλουβιακών υλικών της ευρείας κοίτης και των υλικών αποσάθρωσης του ανάντη ευρισκόμενου ορεινού όγκου. Κάτω: Εντοπισμός θέσης της εδαφικής ρωγμής στο σχετικό απόσπασμα του γεωλογικού χάρτη ΙΓΜΕ.

2.3 Σύνοψη προκαταρκτικών συμπερασμάτων

Ανακεφαλαιώνοντας τις βασικές παρατηρήσεις εδαφικών αστοχιών στην πλειόσειστη περιοχή, στις εικόνες ΓΕΩ16 και ΓΕΩ17 δίνεται συνοπτικά η συνολική εικόνα των αστοχιών κατά μήκος της διαδρομής Δαμάσι – Μεσοχώρι – Αμούρι και Ζάρκος – Πηνειάδα – Κουτσόχερο αντίστοιχα.

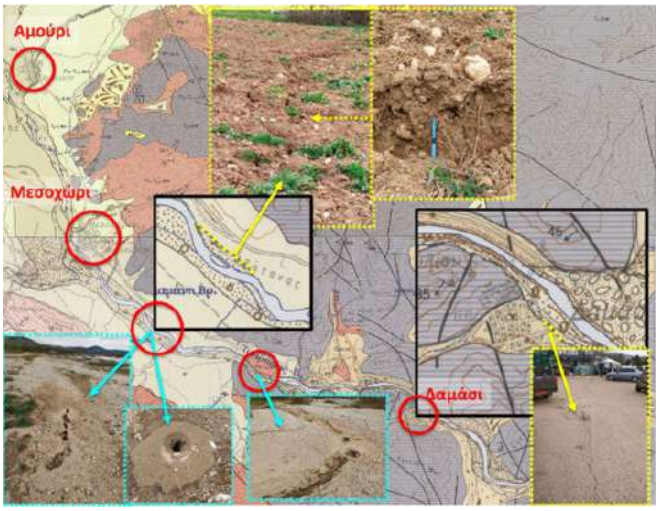
Τα κύρια φαινόμενα τα οποία παρουσιάζουν ιδιαίτερο γεωτεχνικό ενδιαφέρον είναι οι παρατηρηθείσες, ενδεικτικά, ρευστοποιήσεις στις ευρείες κοίτες των ποταμών Τηταρήσιου και Πηνειού, οι οποίες είναι κατά περίπτωση ιδιαίτερα εκτεταμένες

για τα μέχρι σήμερα ελληνικά δεδομένα και χρήζουν περαιτέρω διερεύνησης. Εδαφικές μετακινήσεις στα όρια μεταξύ της νεότερης και της ευρύτερης κοίτης (παλαιοκοίτης) του ποταμού Τηταρήσιου που παρατηρήθηκαν σε δύο θέσεις (1.5km από το Μεσοχώρι κυρίως και δευτερευόντως στο Δαμάσι) χρήζουν επίσης περαιτέρω διερεύνησης σε σχέση με τη διαφοροποίηση της απόκρισης των γεωλογικών σχηματισμών της νεότερης και της παλαιότερης κοίτης και σε σχέση με πιθανές επιπτώσεις στις παρατηρηθείσες δομικές βλάβες στο Δαμάσι.

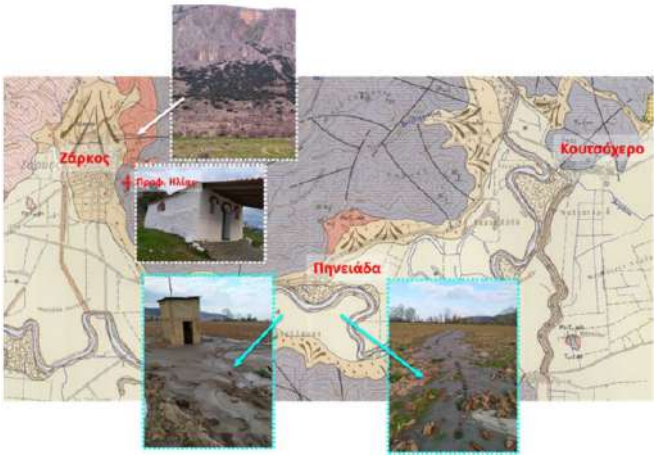
Εικόνα ΓΕΩ13. Φωτογραφίες αποτύπωσης της εδαφικής ρωγμής πεταλοειδούς σχήματος με ένδειξη της διάστασής της ως προς τη σχετική οριζόντια και την κατακόρυφη μετακίνηση των δύο μερών. (Συν/νες θέσης φωτογραφίας: N39°44'10.01"; E22°6'56.87" (αριστερά πάνω), N39°44'9.87"; E22°6'56.96" (δεξιά πάνω), N39°44'10.39"; E22°6'55.99" (αριστερά κάτω) N39°44'11.31"; E22°6'54.15" (δεξιά κάτω))

Εικόνα ΓΕΩ14. Αποτύπωση εκτεταμένης ρευστοποίησης σε θέσεις νοτίως της Πηνειάδας πλησίον του ποταμού Πηνειού (Θέση L3) (Συν/νες θέσης φωτογραφίας: N39°34'53.21"; E22°10'39.77" (αριστερά), N39°34'54.57"; E22°10'41.94" (δεξιά))

Εικόνα ΓΕΩ15. Αποτύπωση εκτεταμένης ρευστοποίησης σε θέσεις νοτίως της Πηνειάδας πλησίον του ποταμού Πηνειού (Θέση L4) (Συν/νες θέσης φωτογραφίας: N39°34'56.05"; E22°10'8.24" (αριστερά), N39°34'56.18"; E22°10'8.16" (μέση), N39°34'56.04"; E22°10'8.25" (δεξιά))



Εικόνα ΓΕΩ16. Συνολική εικόνα αποτύπωσης εδαφικών αστοχιών κατά μήκος της διαδρομής Δαμάσι – Μεσοχώρι – Αμούρι (Διαδρομή 1) και υπέρθεση αυτών στο σχετικό απόσπασμα του γεωλογικού χάρτη ΙΓΜΕ



Εικόνα ΓΕΩ17. Συνολική εικόνα αποτύπωσης εδαφικών αστοχιών κατά μήκος της διαδρομής Κουτσόχερο – Πηνειάδα - Ζάρκος (Διαδρομή 2) και υπέρθεση αυτών στο σχετικό απόσπασμα του γεωλογικού χάρτη ΙΓΜΕ

(Το πλήρες κείμενο της έκθεσης, που περιλαμβάνει και το κεφάλαιο **3. ΑΠΟΚΡΙΣΗ ΚΑΤΑΣΚΕΥΩΝ**, ευρίσκεται:

- Στο αποθετήριο **Zenodo** και είναι διαθέσιμο από το URL: http://doi.org/10.5281/zenodo.4641200
- στην ηλεκτρονική διεύθυνση της ιστοσελίδας του ΙΤΣΑΚ (http://www.itsak.gr/news/categories/24
- στις ανακοινώσεις της ιστοσελίδας του Τμήματος Πολιτικών Μηχανικών του ΔΠΘ: https://civil.duth.gr/anakoinoseis)

ΑΡΘΡΑ

Water inflows in deep excavations in karstified rock
A spotlight on Qatar

Evangelos Georgopoulos

Since the dawn of mankind, underground structures, either natural or manmade, were part of life. From the Eupalinian Aqueduct built in the sixth century BC to the deep excavations for the high-rise buildings of Manhattan skyline, to the Doha Metro, the geotechnical sector has become a very specialised industry.

To achieve a smooth design-construction synergy, it is essential to appoint experienced designers to achieve the correct results. In this field, as in others, nature provides many challenges and we must draw lessons from failures, improve techniques and use all our resources of creativity to succeed.

What are the key factors impacting deep excavations?

Deep excavations are required to accommodate buildings, shafts or other local underground structures related to urban expansion. From a geotechnical perspective, the geology, the stratigraphy, the groundwater regime and the surrounding geometrical and loading restraints must be considered.

Although all factors are important, any potential stability problem can be accommodated with a more robust retaining system. The presence of underground water, if not properly considered and managed, can produce significant delays in construction and increase the cost. The full understanding of which remains unknown until the works are out of the ground and reaching skywards. As such, these projects typically face many uncertainties and significant risk such as:

- unreliable predictions of ground conditions;
- complex technological challenges; and
- the need for intensive investigations before and during construction.

These factors, coupled with the different interests of those either directly or indirectly involved, almost always leads to disputes, either between the Contractors with the Designer for not properly assessing the prevailing conditions or between the Contractors and the Clients for unforeseeable conditions.

Going underground requires the acquisition of the substratum's knowledge by understanding the geology anticipated and determining the required support system for the excavation. It is also mandatory to understand the surroundings to establish the loading conditions from buildings or identify potential obstacles that will require special handling like existing underground utilities or deep founded buildings. Although the above could allow the designer to propose and design the required support system in relation to the geology and loading conditions, the deep knowledge of the groundwater regime is critical, because the improper treatment of such information may lead to unforeseen conditions during the construction.

The groundwater circulation is related to the porosity of the underground mass and categorised into two main categories (i) primary and (ii) secondary, although other types of porosity exist. The primary porosity is associated with the original depositional texture of the sediment and applies to soil formations, whilst the secondary porosity is related to the water circulation through openings in rocks, like discontinuities, fissures and fractures (also characterised as fractured flow) or voids in karstified formations.

Karstification – how to minimise flooding

Karstification usually refers to the process where carbonate formations like limestone, dolomites and gypsum are exposed to leeching and dissolution by atmospheric or brackish water. When the rock formations dissolve, openings, vugs and caves are formed, called karst. The karsts can be filled with water, soil or be empty, depending on the hydrogeological regime and history of the area. When a karst is full of water, it can be connected to a larger water reservoir, such as the sea, with unlimited drainage capacity and, if encountered during construction and not treated properly, may potentially result to the flooding of the excavation (Figure 1). It is therefore essential to identify the existence of karsts early, and the groundwater level and permeability of the formations prior to any excavation works to properly design the required dewatering system, the water management and the potential contingency measures.

Figure 1. Flooded deep excavation after encountering a karst at Doha Souq station, Doha metro gold line underground.

To accurately simulate the potential water inflow, permeability tests of the formations (falling head, rising head and pump-out tests), sampling boreholes to describe the stratigraphy, and geophysical surveys to identify the existence of large cavities/karsts are required.

Underground water management – the importance of being aware

Depending on the size of the karst, the persistence of the openings, the potential connection with water sources in relation to the location of the excavation and the expected volume of water to be managed may vary. It is critical to consider the volume of water to be managed during construction activities and the stormwater network capacity to accommodate the dewatering requirements.

Contractors should always be aware of the criticality of the water volume to be managed, otherwise if this is not correctly estimated, the dewatering system will be inadequate and the risk of flooding the excavation will be increased.

WATER DISPOSAL – THE KEY MEASURES

Alternative ways to dispose of the water from the discharge is either to the sea or deep recharge wells. The disposal to the sea requires environmental impact assessments (EIA) and studies to be carried out before any dewatering works, which must be approved by the relevant authorities and may cause delays. Additionally, the water that can be disposed to the sea must be clean from particles, therefore, the construc-

tion of sedimentation tanks is a requirement. The solution of deep recharge wells (400m deep) requires time (circa 4 months) and has an increased cost (circa $1,000,000 in 2015 prices in Qatar), whilst the discharge capacity can only be verified after the completion of the well. If the capacity is not as per the required discharge volumes, additional wells will need to be constructed which further increase the cost and time required. Both solutions (sea and deep wells) require activities that are time consuming and can be time-critical if not considered at the beginning of the project, such as the EIAs and approvals or the construction of the wells.

The main known issues arising for each of the potential water disposal measures are:

1. ease of construction
2. prerequisites for developing the solutions
3. time required from conception; and
4. cost.

WHICH DISPOSAL MEASURE IS MOST EFFECTIVE?

Table 1. By assigning a score from 1 to 3 (3 = most complex) for the known issues and for each of the three disposal solutions, the following simplified matrix id developed.

	disposal to...		
known issues	**network**	**sea**	**deep wells**
Construction	1	2	3
Prerequisites	1	3	2
Time required	1	3	3
Cost	1	2	3
Sum	4	10	11

As observed, the network disposal solution is the most cost and time effective, but it's not always possible and detailed water volume calculations must be performed to accurately estimate the discharge requirements.

If the discharge requirements are underestimated and the network system has been chosen as the preferable solution, the network will not be able to accommodate the balance of the water and the excavation will be flooded until an alternative solution can be considered and become operational.

In case the requirements have been overestimated, the contractor will have an unnecessary cost impact if the deep well has been considered, or delays until the required environmental studies and permits approved for the disposal to the sea.

With this in mind, the identification of major karstic features and the determination of the formations' hydraulic properties are critical. The appropriate simulation of the potential water inflows and the determination of the measures required prior to excavation activity will reduce the risk of flooding and/or water disposal that directly increase the cost of the project, reduce the productivity (disruption) and create delays.

Karstification in action: a spotlight on Qatar

The ground surface across Qatar is generally a low relief and the peninsula is elliptical in shape as it extends out into the Persian Gulf. The topographical features largely reflect the structures of the sedimentary rocks which underlie the mainland. The main features include a broad shallow-dipping arch trending north-south along much of the length of the peninsula. More notable features are the numerous widely scattered depressions due to dissolution of limestone.

There are no perennial surface waterways in Qatar, and surface water is only present in the form of ponds or reservoirs. The drainage channel networks, known as wadis, are ephemeral and not well defined. The drainage system in Qatar is considered "endorheic" as the drainage network does not channel the majority of surface water run-off into the sea but via wadis and overland flow to inland surface depressions. In Doha, there is little evidence of these wadis which is due to the urbanisation of the city. These wadis could be associated with soft fine-grained deposits, erosion or incision of the limestone rockhead and a greater density of karst features.

The geology of Doha, from the surface downwards to the depth of common urban excavations (circa 40m depth), consists of a lean layer of fill material and marine deposits, Simsima Limestone, Midra Shale and Rus Limestone Formation.

In Doha, two superficial aquifers have been identified, namely, the "superficial aquifer" and the "shallow aquifer", which correspond to Simsima Limestone and Rus Limestone Formation, respectively. The two aquifers are separated by the Midra Shale which constitutes a heterogeneous aquitard. Regional groundwater movement is generally from west to east i.e. from inland towards the coast.

The local hydrogeological conditions of Doha, with emphasis to the coastal area, are governed by horizontal hydraulic anisotropy in depth, mainly observed in the interface between the Simsima and Midra Shale. The respective part of the formations is characterised by increased permeability due to the almost impermeable layer of the shale and the circulation of the Simsima's aquifer groundwater in the respective interface, producing karstic voids and fissures at the limestone.

The respective anisotropy is a known phenomenon in the area and has been observed in almost all deep excavations. Since its a zone of higher permeability overlay on an almost impermeable layer of shale, increased water inflows are expected as the excavation approached the impermeable layer (see Figure 2).

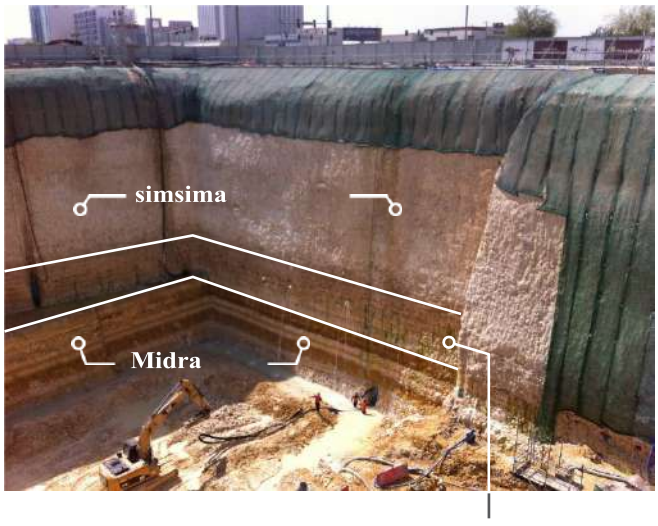


Figure 2. Zones at the interface between simsima limestone and midra shale with increased permeability, Al Matar/C-ring station of Doha metro rede line south underground.

According to the in situ data acquired during the excavations in Doha, Simsima Limestone, which overlays Midra Shale, is characterised by horizontal anisotropy in permeability, resulted mainly from the fact that zones with higher karstification (or transition zones) are observed at the interface area between limestone and shale. Since this transition zone is almost governing the "hydraulic behaviour" of the formation, it is important to be simulated directly in the flow net calculations procedure. The flow net must be simulated accordingly by performing a sensitivity analysis of the complex hydraulic behaviour of the formations to quantify the expected water inflows during the excavations.

Mitigation measures – getting one step ahead

When the karstified areas and the extent of the voids are identified, and the potential water inflows are calculated, specific measures must be considered to reduce the potential water inflows and reduce the risk of flooding of the excavations.

To reduce water inflows, mitigation measures such as karst void mitigation grouting are commonly used, which involves targeted grouting at the areas of karstification to fill the big voids that potentially lead to increased water quantities into the excavation.

The effectiveness of karst void mitigation has been investigated in one of the Metro Stations, located in the coastline of Doha. The model that has been taken into consideration has also been encountered during the excavation. The model simulated has three karstic zones of 1m thickness each. The karst void mitigation grouting has been constructed at the areas of the karstification only as this happened during construction. The water inflows calculated with and without grouting, as well as the reduction of the water inflows in the excavation due to the effectiveness of the grouting is presented below.

Table 2. Water inflows and effectiveness of karst void mitigation grouting demonstrated with calculations in one of the metro stations in the coastline of Doha.

Water inflows [m^3/h]		
Without karst void mitigation grouting	**With low effective karst void mitigation grouting**	**With high effective karst void mitigation grouting**
2,000	1,800	1,200
Reduction in inflows [%]	10%	40%

As per the investigations carried out in Qatar, the use of targeted conventional mitigation methods can reduce the water inflows by up to 40%. This directly reduced the construction cost, the potential of disruption and the delays for contingencies.

Reducing delays, disruption and excessive costs

As evidenced from the experience gained in Qatar, a highly karstified area, the execution of the required investigation works prior to the excavation is of paramount importance for the accurate prediction of the water inflows in deep excavations. This will highlight the water disposal requirements and will guide to the proper discharge solution by reducing the risks of delays, disruption and excessive construction cost, and eventually the likelihood of a high cost dispute.

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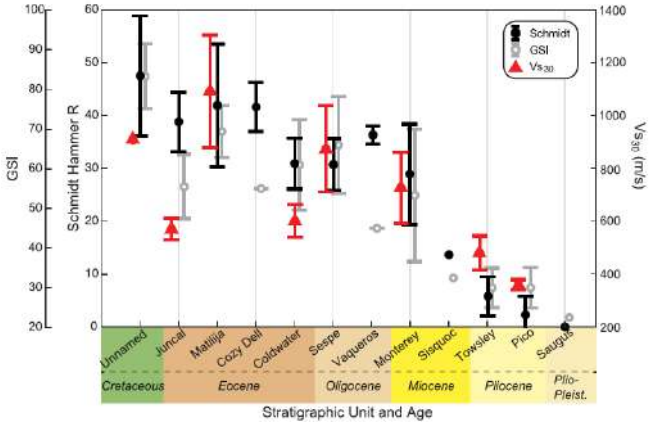
Profiles of Near-Surface Rock Mass Strength Across Gradients in Burial, Erosion, and Time

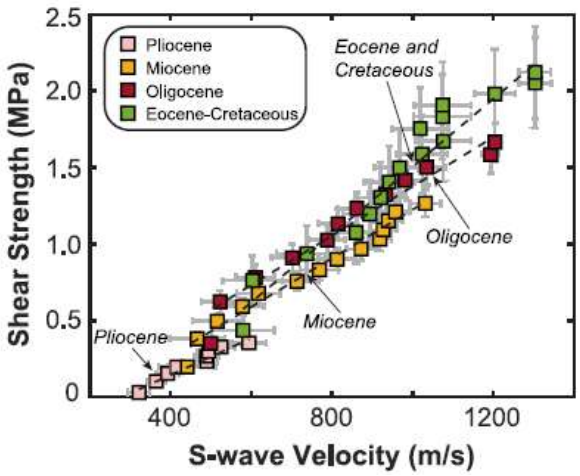
Kirk F. Townsend, Marin K. Clark, Dimitrios Zekkos

(JGR Earth Surface, Volume 126, Issue 4, April 2021, e2020JF005694, https://doi.org/10.1029/2020JF005694, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020JF005694)

Abstract

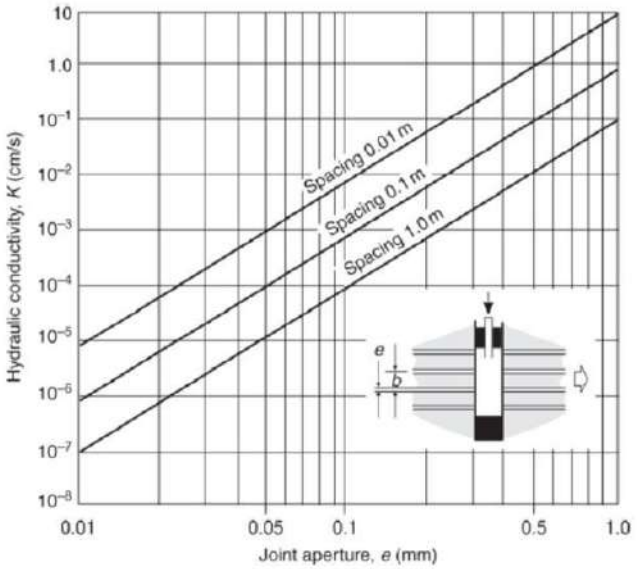
Rock mass strength is recognized as an important control on landscape morphology and evolution. However, the controls on rock strength in mountainous topography remain poorly characterized, in part because strength remains challenging to quantify at spatial scales relevant to geomorphology. Here we quantify the mechanical properties of rock masses using subsurface S-wave velocities, Schmidt hammer hardness values, and Geological Strength Index (GSI) observations. We produce shallow depth profiles of rock mass shear strength using intact rock hardness as measured from a Schmidt hammer, and assessment of the structure and surface conditions of fractures using GSI. We apply these techniques to the Western Transverse Ranges, southern California, USA, where gradients in stratigraphic age and erosion rate allow us to evaluate our methodology. We resolve strength differences of 200 kPa to ~5 MPa that appear to be related to diagenetic changes associated with the maximum burial depth of young clastic sedimentary rocks. For rocks of the same lithologic type, stratigraphic age, and inferred burial histories, we resolve smaller differences in strength (300 kPa–1.5 MPa) that appear to be positively correlated with mean erosion rates. We suggest that the increase in strength with increasing erosion rate reflects decreased residence time in the weathering zone for ranges experiencing faster fault slip rates. These findings demonstrate up to an order of magnitude variability in strength with respect to burial, erosion, and time for lithologically similar rocks. As such, lithology alone is unlikely to adequately capture the role of rock strength in landscape evolution.



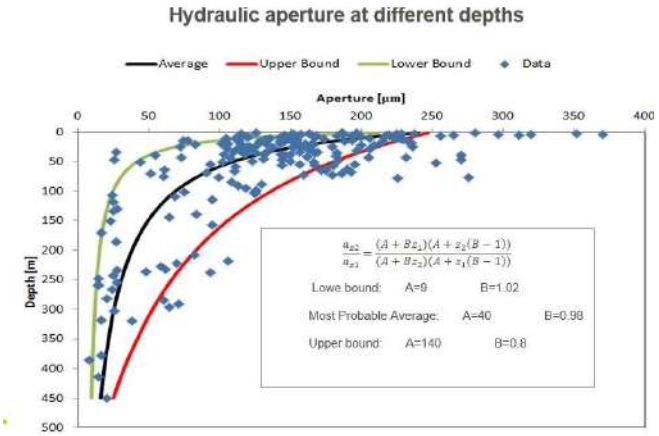


Reminder 3: Aperture of Discontinuities and Hydraulic Conductivity of Jointed Rocks

As a well-known knowledge, discontinuities control the hydraulic conductivity of the jointed rocks. Based on cubic law (Snow, 1965, 1969), the hydraulic conductivity of a joint set with spacing of "s" (in meter) and hydraulic aperture of "a" (in meter, hydraulic aperture represents the fracture aperture adjusted to address the fracture roughness, tortuosity, etc.) can be calculated as K=g(a^3)/12sv (g is gravitational acceleration and v is the kinematic viscosity of water which is 1.004e-6 m2/s at 20°C). As an example, hydraulic conductivity of one joint set with aperture of 0.5 mm and spacing of 1 m is approximately 1e-4 m/s (please see following graph from Brady and Brown, 1985).



This equation shows that aperture has the highest impact on the hydraulic conductivity as if it changes only 2.15 times, the hydraulic conductivity will approximately change one order of magnitude. The discontinuity spacing must change 10 times (for example from 0.1 m to 1 m) to have one order of magnitude changes in hydraulic conductivity. Priest (1993) presented an approach to calculate the hydraulic aperture of the pre-existing discontinuities in the test intervals of Lugeon test. Following graph shows the estimated range for hydraulic aperture versus depth developed based on Priest (1993) approach. You can find more details on this here: [https://www.unsworks.unsw.edu.au/permalink/f/5gm2j3/unsworks_12891)](https://www.unsworks.unsw.edu.au/permalink/f/5gm2j3/unsworks_12891).

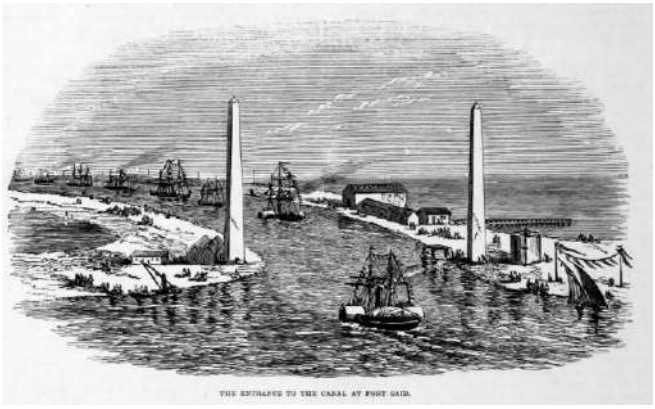


This graph can be used to estimate the hydraulic conductivity range from cubic law (rough estimation) or calculate the hydraulic conductivity tensor from Snow (1965), Oda (1985) or Zoorabadi (2014) methods. It also can be used to determine the safe grouting pressure range (https://www.linkedin.com/feed/update/urn:li:activity:6779878515975294976/) or to estimate the normal stiffness of fractures at different depths.

(Mahdi Zoorabadi, March 24, 2021, https://www.linkedin.com/pulse/reminder-3-aperture-discontinuities-hydraulic-jointed-mahdi-zoorabadi)

December 1869: The Suez canal opens

140 years after its construction, the Suez canal remains one of the most impressive and important thoroughfares on the planet. And *The Engineer* announced its opening in a suitably triumphant tone. "The Suez Canal has been blessed; the Suez Canal has been opened; the Suez Canal is a constructive success."



"I write now in quiet, that is to say comparative quiet," wrote our correspondent. "Notwithstanding the Babel around me, the shouting, the music, etc, I consider myself in perfect peace, compared with the uproar and excitement to which we have lately been subjected. I suppose more gunpowder has been burned within the last eight and 40 hours than was ever burned before in salute-firing."

Verily engineers can work wonders with this little earth of ours!

The hullabaloo soon gave way to nervousness as the first ships entered the canal. "The great day dawned anxiously," the article continued, "we saw steamers, one after another, slowly enter the canal until far, far away to the horizon we could trace a long line of craft slowly wending their way…'

The opening of the canal was not without teething problems and a number of ships ran aground, but this didn't dampen *The Engineer*'s enthusiasm for the project. 'As I conclude this letter,' wrote the magazine's correspondent, 'I am looking upon the waters of Lake Timseh, in the midst of the land of Goshen. A few months ago it was dry… now it forms a magnificent sheet of salt water — an inland sea. And on its calm bosom lies over 40 ships… 40 ships in the midst of the desert — in the barren and dry land where no water was! Verily engineers can work wonders with this little earth of ours!"

(Jon Excell / THE ENGINEER, 7th December 2009,
https://www.theengineer.co.uk/december-1869-suez-canal)

ΝΕΑ ΑΠΟ ΤΙΣ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

ΕΛΛΗΝΙΚΗ ΕΠΙΤΡΟΠΗ ΣΗΡΑΓΓΩΝ και ΥΠΟΓΕΙΩΝ ΕΡΓΩΝ (Ε.Ε.Σ.Υ.Ε.)
Greek Tunnelling Society Young Members

Overview

Following the decision of the International Tunnelling Association (ITA) for the establishment of the "Young Members Groups" for young professionals in the tunnelling and underground space industry, the Greek Tunnelling Society (GTS) decided to create a national "Young Members Group" in 2014. The GTSym is open to all young tunnelling professionals and students under the age of 35. The main objectives of the group as described by the GTS are: 1. To record and communicate existing experience and knowledge in design, construction, operation and maintenance of tunnels and underground structures in Greece and where Greek professionals have been active. 2. To disseminate information related to the development and implementation of new technologies and methods in underground projects. 3. To act as a forum for young members within the GTS, keep a direct relationship with the Young Members Groups of the ITA, and attract new members in other GTS Working Groups. 4. To facilitate access for young professionals to career opportunities in tunnelling and underground construction in Greece and abroad. 5. To inform school and university students of the conditions, prospects, and opportunities within the tunnelling and underground works industry. 6. To organise educational and training events for young professionals. 7. To organise visits to relevant construction sites in Greece and abroad.

Website https://www.eesye.gr/omicronmu940deltaalpha-nu941omeganu-muepsilonlambda974nu.html

Σας ενημερώνουμε ότι η Ομάδα έχει σελίδα στο LinkedIn. Ακολουθήστε τη σελίδα μας για όλα τα νέα και τις δράσεις μας: https://www.linkedin.com/company/greek-tunnelling-society-young-members-group-gts-ymg

International Society for Soil Mechanics and Geotechnical Engineering

ISSMGE News & Information Circular
April 2021
www.issmge.org/news/news-and-information-circular-april-2021

1. 20ICSMGE / 7iYGEC – NEW DATES – MAY 2022

New dates have been confirmed for the conferences in Sydney as follows;

7iYGEC - Friday 29 April-Sunday 1 May 2022
20ICSMGE – Sunday 1 May – Thursday 5 May 2022.

For more information, please visit the conference website (https://icsmge2021.org/) which is in the process of being updated.

2. CORPORATE ASSOCIATES' PRESIDENTIAL GROUP

The March 2021 CAPG update (https://www.issmge.org/corporate-associates/corporate-associates-presidential-group) has important information on the soon upcoming CAPG specialty session at the International Foundations Conference and Equipment Expo (IFCEE), in Dallas, USA, May 10 -14, 2021, the CAPG sessions at the 20th ICSMGE in Sydney (May 2022), the successful completion of the world wide online sessions for the ISSMGE Overdesign Survey, planning of CAPG contributions to the ISSMGE virtual Time Capsule project and other important areas.

3. ISSMGE TC217 LAND RECLAMATION SEMINAR SERIES

The committee of TC217 is hosting a trilogy of online seminars on topics relating to land reclamation from consultant, specialist contractor and academic perspectives. Please register your interest to attend these seminars here: https://forms.gle/QLPkWYzFquxbqJPz7

Seminar Programme:

1. Construction and Reclamation of the SARB Islands offshore the coast in Abu Dhabi by Dr. Ir. Patrick Mengé - 11 March 2021, 7pm (GMT+8)

2. Innovative Approaches to Land Reclamation in Singapore by Er. James Lam Pei Wei - 15 April 2021, 7pm (GMT+8)

3. Land Reclamation using Soft Clay by Prof. Chu Jian - 20 May 2021, 7pm (GMT+8)

4. Application of Machine Learning in Cement Stabilisation in Land Reclamation by Assoc. Prof. Darren Siau Chen Chian - 20 May 2021, 7:30pm (GMT+8)

4. 3rd HUTCHINSON LECTURE - 3rd JTC WORKSHOP – NORWAY, 2022 – CALL FOR PROPOSALS

The Joint Technical Committee (JTC1) on Natural Slopes and Landslides of the Federation of the International Geo-engineering Societies (FedIGS) is organizing the 3rd JTC1 workshop, which will be held in Norway in Spring, 2022; the provisional title of the event is Landslide initiation, prediction and risk mitigation.

The workshop will host the 3rd Hutchinson Lecture, which has been established by the same JTC1 to award a scholar, aged 42 or less at the time of the event, who has significantly contributed to the development of knowledge in the field of slope stability and landslides. The Hutchinson Lecture should deal with a subject consistent with the workshop issues. The lecture will be published in an international journal.

The Hutchinson lecturer, who should have a disciplinary background from one or more of the domains of the geosciences, will be chosen - by vote of JTC1 Committee members - among candidates proposed by national societies. All countries are then asked to propose their own candidate. The proposals, accompanied by the candidate CV, should be submitted to the JTC1 chairman, Luciano Picarelli, by September 15th 2021 (luciano.picarelli@unicampania.it) .

5. BULLETIN

The latest edition of the ISSMGE Bulletin (Volume 15, Issue 1, February 2021) is available from the website https://www.issmge.org/publications/issmge-bulletin/vol-15-issue-1-february-2021

6. ISSMGE FOUNDATION

The next deadline for receipt of applications for awards from the ISSMGE Foundation is the 31st May 2021. Click **here** for further information on the ISSMGE Foundation.

7. CONFERENCES

For a listing of all ISSMGE and ISSMGE supported conferences, and full information on all events, including deadlines, please go to the Events page at https://www.issmge.org/events. However, for updated information concerning possible changes due to the coronavirus outbreak (ie. postponements, cancellations, change of deadlines, etc), please refer to that specific event's website.

As might be expected, many events have been rescheduled and we update the Events page whenever we are advised of changes.

The following are events that have been added since the previous Circular:

ISSMGE Events

THE SECOND INTERNATIONAL CONFERENCE ON PRESS-IN ENGINEERING 2021, ONLINE - 19-06-2021 - 20-06-2021
ONLINE, Japan; Languages: English and Japanese; Organiser: International Press-in Association (IPA); Contact Information: ICPE2021 Organizing Committee; 5F, Sanwa Konan Bldg, 2-4-3 Konan, 2-4-3 Konan, Minato-ku, Phone: +81-(0)3-5461-1191, Fax: +81-(0)3-5461-1192, Email: tokyo@press-in.org; Website: http://icpe-ipa.org; Email: icpe2021@gmail.com

FIFTH INTERNATIONAL CONFERENCE ON NEW DEVELOPMENTS IN SOIL MECHANICS AND GEOTECHNICAL ENGINEERING - 30-06-2022 - 02-07-2022
Atatürk Cultural and Congress Center Near East University, Nicosia, Cyprus; Language: English; Organiser: Turkish Society of Soil Mechanics and Geotechnical Engineering and Near East University; Contact person: Cavit ATALAR; Address: Near East Boulevard; Phone: 05338342829; Fax: 00903922236461; Email: cavit.atalar@neu.edu.tr; Website: http://zm2020.neu.edu.tr;

NON-ISSMGE Events

LECTURE-1 ON MSE WALLS (2ND EDITION OF AGERP LECTURE SERIES) - 16-04-2021 - 31-12-2021
Online (Zoom), Brisbane, Australia; Language: English; Organiser: AGERP Lecture Series; Contact person: Dr. Partha Mishra and Professor Sarat Das, Convenor, AGERP Lecture Series; Email: hello.agerp@gmail.com; Website: http://www.age-rp.com

DFI DEEP MIXING CONFERENCE 2021 AN ONLINE CONFERENCE - 01-06-2021 - 17-06-2021
Online, United States; Language: English; Organiser: Deep Foundations Institute; Contact person: Angie Gibble, Address: 326 Lafayette Ave, Phone: 9734234030, Email: agibble@dfi.org, Website; http://www.dfi.org/DM2021; Email: events@dfi.org

16TH INTERNATIONAL CONFERENCE OF THE INTERNATIONAL ASSOCIATION FOR COMPUTER METHODS AND ADVANCES IN GEOMECHANICS – IACMAG - 30-08-2022 - 02-09-2022
Politecnico di Torino Conference Centre, Italy; Language: English; Organiser: Politecnico di Torino; Contact person: Symposium srl, Address: via Gozzano 14; Phone: +390119211467; Email: info@symposium.it; Email: marco.barla@polito.it;

Introducing Time Capsule Project (TCP) Blog Posts

Recently, the ISSMGE initiated a project to capture past, current and future issues in Geotechnical Engineering practice. While much of the Time Capsule Project (TCP) activities are through formal channels (e.g. Technical Committees, Member Societies) the opinion of everyday engineers, the foundation of practice, is paramount.

In order to debate past, current and future issues in Geotechnical Engineering, we are welcoming and publishing short articles on the ISSMGE website. Articles will be displayed for a limited time and views expressed need not be shared by the ISSMGE or held strongly by authors. Examples of current and upcoming articles include:

- We don't need no education – Charles John MacRobert (Stellenbosch University)
- Ethics in Geotechnical Engineering – Emilio Bilotta (University of Naples Federico II)
- Mind the Gap: Research and practice – Ceres Chung (Geotechnical Engineering Office, Hong Kong)
- Archaeology of Geotechnical Engineering in Argentina – Roberto Terzariol (National University of Cordoba, Argentina)

We encourage you to reflect on your practice of Geotechnical Engineering and think how you could contribute to this great debate. We challenge you to write 200-400 words on any topic that will generate debate within the Geotechnical Engineering profession. Click here to submit your article for consideration.

In Memoriam: Distinguished Professor Richard D. Woods (1935-2021)

4th September 1935 - 27 January 2021

Dear Colleagues,

It is with great sadness that we share the news that Professor Dick Woods passed away on January 27, 2021 with his family by his side.

Richard D. Woods was born September 4, 1935 to Andrew and Beryl (Evens) Woods in Lansing, Michigan. He graduated from Sexton High School in Lansing in 1953, obtained a BS in Civil Engineering in 1957, MS in Civil Engineering in 1962 from Notre Dame University. From September 1957 through August 1960 he served in the United States Marine Corps as an engineering officer. In 1967 he received his Ph.D in Civil Engineering from the University of Michigan and went on to become a member of the University of Michigan faculty for over 35 years.

Before beginning his career at the University of Michigan, Professor Woods served as a lieutenant in the U.S. Marine Corps, conducted research at the Air Force Weapons Laboratory at Kirkland Air Force Base, and taught at Michigan Technological University in Houghton. Professor Woods joined the University of Michigan faculty as an Assistant Pro-fessor in 1967 and was promoted to Associate Professor in 1971 and Professor in 1976. He served as the Chair of the Department of Civil and Environmental Engineering from 1994 to 2001. After formal "retirement" from the University of Michigan, Professor Woods taught at Notre Dame University one semester each year for nearly a decade. Reestablishing himself in Ann Arbor, Professor Woods once again taught graduate classes and advised PhD students at the University of Michigan throughout the 2010's. His geotechnical engineering consulting efforts would continue through 2020.

Prof. Woods is best known for his pioneering research in soil dynamics, foundation engineering, and engineering geophysics. He authored over 80-refereed publications and chaired 21 Ph.D. theses. Among Professor Woods' numerous awards are the Collingwood Prize from the American Society of Civil Engineers and the Terzaghi Lectureship from the ASCE Geotechnical Engineering Division. He was inducted into the National Academy of Engineering in 2003.

In addition to being a giant in our field, Professor Woods was an extremely gracious and kind colleague and mentor who loved the University of Michigan and his friends and collaborators throughout the world. He was a driving force in the ASCE Geo-Institute and in USUCGER. Dick will be dearly missed.

Dick was preceded in death by his wife of 55 years, Dixie L. (Davis) Woods, in 2012 and his daughter Kathleen (Woods) Laird in 1981. He is survived by his daughters, Cecilia Woods of Dexter and Karen Woods Bochenek (Andrew) of Royal Oak, grandson Trevor Laird (Nina) of Glasgow, Scotland, granddaughters Jane Woods (Ross) of Cincinnati, Ohio, Audi Woods of Ypsilanti , Sarina (Parks) Pankey (Kevin) of Belleville, Tori Parks of Ypsilanti, great granddaughters Daisha Wilson, Siobhan Woods, Alanna Armstrong, Hella Woods, and great grandsons Zyhare Scott, and Kevin Pankey jr.

Rest in peace Professor Woods.

The following obituary is distributed through the United States Universities Council on Geotechnical Education and Research (USUCGER) by Prof. Roman Hryciw of the University of Michigan.

ISRM International Society for Rock Mechanics and Rock Engineering

News

www.isrm.net/noticias/?tipo=1&todas=1&show=info

New ISRM course on Monitoring Data Interpretation by Prof. Wulf Schubert on the ISRM website
2021-04-19

The new ISRM course on "Monitoring Data Interpretation" by Prof. Wulf Schubert, is available on the ISRM website, in open access.

Three nominations for ISRM President 2023-2027 were received
2021-04-27

The three candidates are:
- Anna Maria Ferrero, nominated by the National Group of Italy,
- Jian Zhao, nominated by the National Group of Australia,
- Seokwon Jeon, nominated by the National Group of Korea.

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN AITES | ITA INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

ITA-CET online lunchtime lecture is pursuing its path!

As mentioned in our last newsletter, these lectures are open to a wide public and will take place live, on the second Tuesday of every month from 13:00 hours to 14:00 hours Paris time. Each event will include key lectures, followed by a question and answer session. Lecturers will be top professionals in the tunnelling and underground space community, notably

from the ITA's Working Groups and Committees. Industry representatives and project owners will be asked to intervene on a regular basis, in order to give different viewpoints.

The first session centered on **"From rock mechanics to drill and blast"** gathered a total of 196 participants from all over the world. - in total a massive 47 countries were represented by participants!

The second one focused on **"Contractual practices and the FIDIC Emerald book".** The session included a case study from a contractor, lectures on the FIDIC Emerald book, and a Q&A session to finish.

The last installment offered a lecture on the theme of «**Compressed air**» including a first lecture by Donald Lamont (animateur of ITA WG5), a case study from Tim Babendererde from BabEng,

After those first three successful events which took place on 9th February, 9th March and 13th April, on the ITA-CET Committee and ITACET Foundation are pleased to announce the next installment of the lunchtime lecture series which will be on **"Modern approaches to tunnel waterproofing"** the 11th May.

The provisional schedule and topics for the next lectures over the coming months is (https://about.ita-aites.org/wg-committees/ita-cet/news):

Date	Topic
11th May	Waterproofing
8th June	Automation in Tunnelling
13th July	Into the future
10th August	Life Cycle Management
14th September	Digitalization in Tunnelling
12th October	Safety in Operation
9th November	Hydro Power
14th December	Mechanized Tunnelling

More details on the next sessions, including how to register, can be found on the ITACET Foundation website: www.itacet.org

Online training session: Calculation methods for tunnel design

ITACET Foundation in association with AMITOS, the Mexican association of tunnel and underground space engineers will organised an online training session. The course is 'Calculation methods in tunnel design' and will be run over 4 half-day sessions. The sessions will be held on 27 & 29 April and 3 & 5 May 2021.

The objective of this training session is to present the design methods commonly used to assess tunnel stability. Each method is illustrated by an example. Advantages and difficulties when applied to a tunnel project will be highlighted.

More information is available on both ITACET Foundation and AMITOS websites: www.itacet.org and www.amitos.org

Scooped by ITA-AITES #41, 13 April 2021

Underwater tunnel project between Santos and Guarujá advances | Brazil

Malaysia-China joint train project sees 1st tunnel breakthrough | Malaysia

'All roads lead to Rozelle': Halfway mark for Sydney's mammoth spaghetti junction | Australia

Chile-Argentina tunnelling projects planned

Central Interceptor preps for TBM launch | New Zealand

The engineering behind Melbourne's groundbreaking Metro Tunnel project | Australia

China's $422m underground lab will probe massive national nuclear waste dump in remote Gansu

Shortlist announced for Lower Thames Crossing tunnel contract | UK

EWE to explore underground 100% hydrogen storage | Germany

An engineering marvel - China builds green rail linking Laos

Final breakthrough on Bangkok Orange Line Contract E3 | Thailand

The underground vegetable farm thriving in wartime bunkers below London | UK

Scooped by ITA-AITES #42, 27 April 2021

Details of new road tunnel at Glen of the Downs released | Republic of Ireland

Tunnel under Blue Mountains would be world's longest but ruled out as too expensive | Australia

Japan deploys new underground project to fight flooding

Underground DART project set for revival after being shelved a decade ago | Republic of Ireland

Construction of test disposal tunnel under way at Onkalo : Waste & Recycling | Finland

NYC's giant water tunnel begins work on final shafts, following 50 years of construction | United states of America

Estonia, Finland to sign agreement on 100km Baltic tunnel on Monday

Engineering places: Thames Tunnel | UK

Bangalore Metro's sixth tunnelling machine launched from Jayanagar Fire Station to Dairy Circle | India

[Hinkley Point C concrete pour dubbed 'feat of engineering' | UK]

[All parts of 2 subway tunnel boring machines now onsite | Republic of the Philippines]

[TBM breakthrough on the Serravalle tunnel | Italy]

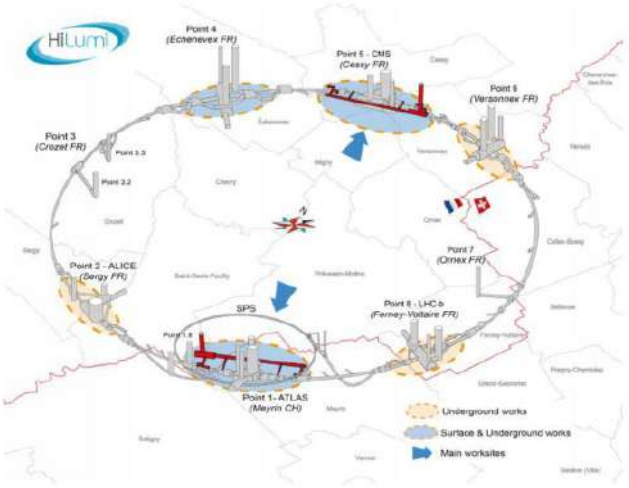
http://www.britishtunnelling.org.uk

CERN's HL-LHC Project

Lecture will be broadcasted live on YouTube
Thursday 20th May 2021 at 18:00 hrs [UTC+1]
https://youtu.be/p1Kv4SE1cJY

Speakers

Pieter Mattelaer – Project Manager Civil Engineering, CERN
James Gillies, PhD – Senior Communications Advisor, CERN



CERN, the European Organization for Nuclear Research, enables international collaboration in the field of high-energy particle physics. CERN designs, builds and operates particle accelerators and the associated experimental areas, which are housed in a complex network of underground tunnels, galleries and caverns in the Geneva Basin. CERN's High-Luminosity LHC project covers two nearly identical construction sites in Switzerland and neighbouring France on which a new shaft, cavern, underground galleries and industrial buildings will be constructed to house new accelerator equipment. The new underground structures have a total length of ± 1.25km and were excavated between 2018-2020 using traditional methods in molasse, close to the existing ATLAS and CMS detector caverns. The works, valued at ± 135 MCHF, are rather complex due to the variety of structures and excavation sections, the connection to the existing LHC tunnel and the access constraints imposed by the single shaft at each site. CERN's project manager for civil engineering will provide an overview of the project from design to construction at a moment in time when the underground works are almost complete. One of CERN's physicists will be available to clarify how the project fits into CERN's physics program.

Managing Safety in Tunnelling

Speaker

Michael William Sanderson *MSc MA CMIOSH*
EHS IC Head, Larson & Toubro

Drawing on his 30+ years of experience in managing safety risks on significant projects, both in India and the UK, Michael's presentation will provide an overview of tunnel collapses he has personally witnessed, explore the role Risk Management plays in the industry, and highlight best practice.

Joint BTSYM / TAIym / ICE London G&S Lecture, Online at : https://youtu.be/pVy-vFVG7BE, Thursday 22nd April 2021 at 12:00 hrs [UTC+1]

The presentation will also compare the differences in safety legislations in the two countries, their impact on Risk and Safety Management, and will discuss the impact of innovation and competency in ensuring safety.

Geotechnical engineering newsletter

FREE TO READ

Geotechnical Research

Geotechnical Research disseminates knowledge on all aspects of modern geotechnics to engineers worldwide. As a Gold Open Access journal, all the of its papers are always free for you to read.

Read the journal now

More papers free to read

Effect of preloaded micropile on the foundation underpinning by centrifuge experiments open access

Engineering properties of clayey soil stabilised with alkali-activated slag

Evaluation of two-stage scaling for physical modelling of soil–foundation–structure systems editor's choice

Global and local sand–geosynthetic interface behaviour

Stick–slip behaviour of mortar–rock interface under high loading rate

Search all our content

Healing the world: a geosynthetics solution

In this Giroud Lecture Dr. Nathalie Touze looks at recent developments in geosynthetics to see how the field is helping to meet the UN's Sustainable Development Goals.

Read now

EVENTS

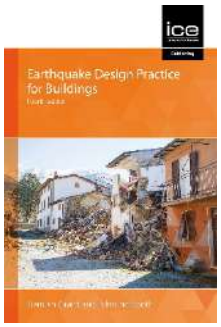
Pore water pressure and total horizontal stress response to EPBM tunnelling in London Clay

FREE: 24 May 2021, Online

The last of this year's Thomas Telford Lecture Series, this event is by the winner of our 2020 Telford Gold Award (the sbest paper overall). They will be discussing their award winning paper on the changes in pore water pressure and total horizontal stress during Crossrail tunnel construction beneath a research monitoring site in London, UK.

Book your place

BOOKS



Piling 2020: Proceedings of the Piling 2020 Conference Print eBook

Earthquake Design Practice for Buildings, Fourth edition Print eBook

Core Concepts of Geotechnical Engineering Print eBook

NEWS

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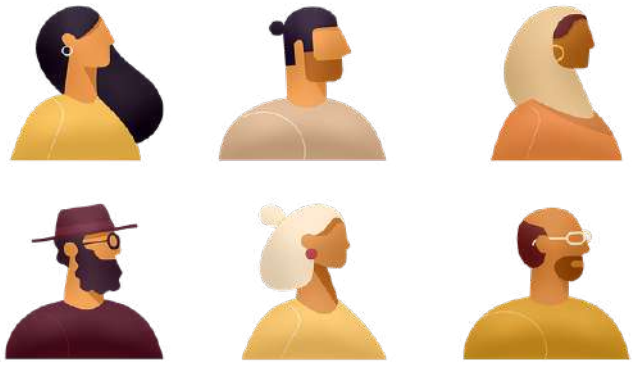

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CHINESE NATIONAL COMMITTEE ON LARGE DAMS

CHINCOLD Update: The video on the Construction Technology for Jingping-I Arch Dam with 4.5m-Lift Concrete uploaded to the Platform

Dear Colleagues and Friends,

Greetings from the Chinese National Committee on Large Dams (CHINCOLD). Welcome to visit CHINCOLD Cloud Platform, a free website with diversified information of dam society at http://www.chincold-smart.com/en

CHINCOLD recently developed a section on the platform to upload a series videos to share technologies and promote technical exchange especially with designers, constructors, engineers and students in developing countries. The videos combined construction site and animation to present technologies applied in typical and famous dams of China.

This month, we would like to introduce the first video, Construction Technology for Jingping-I Arch Dam with 4.5m-Lift Concrete, to you.

The Jinping-I Dam is a tall arch dam on the Jinping Bend of the Yalong River (Yalong Jiang) in Sichuan, China. Construction on the project began in 2005 and was completed in 2014. Its power station has a 3,600 MW capacity to produce between 16 and 18 TW·h annually. Supplying the power station is a reservoir created by the 305-meter-tall arch dam, the tallest in the world.

In dam construction, due to the large amount of cement and massive size of the placement block, the temperature difference caused by temperature rise and drop of confined concrete will produce great temperature stress and the concrete will be susceptible to cracking. In order to further improve the dam construction efficiency, it applied a continuous massive concrete placement scheme represented by a thick lift of 4.5m, but the thickness increase of concrete lift would inevitably deteriorate heat dissipation conditions of the concrete. This video revealed how the Chinese engineers successfully deal with the questions and promote the dam construction.

http://www.chincold-smart.com/en/capacity-building/training/list/1/all

Welcome to watch the videos and inform us which aspects of Chinese dams you are concerned with. You can leave your feedback either on the message board next to the video, or in the "cooperation center" on the homepage of the platform http://www.chincold-smart.com/en/wisdom-lib/cooperation/all/list/1

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

Για τις παλαιότερες καταχωρήσεις περισσότερες πληροφορίες μπορούν να αναζητηθούν στα προηγούμενα τεύχη του «περιοδικού» και στις παρατιθέμενες ιστοσελίδες.

Λόγω της πανδημίας του κορωνοϊού, υπάρχουν αλλαγές είτε στον τρόπο διεξαγωγής των συνεδρίων (με φυσική παρουσία ή virtual), είτε των ημερομηνιών διεξαγωγής κάποιων συνεδρίων. Συνιστάται να ελέγχετε την ημερομηνία διεξαγωγής απ' ευθείας στον ιστότοπο του συνεδρίου.

16th International Conference of the International Association for Computer Methods and Advances in Geomechanics – IACMAG - CHALLENGES and INNOVATIONS in GEOMECHANICS, 03-05-2021, Torino, Italy, www.symposium.it/en/events/2020/16th-international-conference-of-iacmag?navbar=1

9th International Symposium on Geomechanics ISRM Specialized Conference "Applied Geomechanics in Proactive Designs: Opportunities, Challenges and Security", Virtual, 3 - 6 May, 2021, Medellin, Colombia, https://minas.medellin.unal.edu.co/gruposdeinvestigacion/giga/en/symposium-9/about-symposium.html

ATS 2020 AUSTRALASIA TUNNELLING CONFERENCE, 10th – 13th May 2021, Melbourne, Australia, www.ats2020.com.au

TISOLS Tenth International Symposium on Land Subsidence, Living with Subsidence, 17-21 May 2021, Delft - Gouda, the Netherlands, www.tisols2020.org/tisols2020

Virtual 2020 CHICAGO ICTG International Conference on Transportation Geotechnics, May 23 - 26, 2021, Chicago, Illinois, USA, http://conferences.illinois.edu/ICTG2020

Fifth International Conference on New Developments in Soil Mechanics and Geotechnical Engineering, 27 – 29 May 2021, Nicosia, Northern Cyprus https://zm2020.neu.edu.tr/

2021 ICOLD MARSEILLE - ICOLD 27th Congress - 89th Annual Meeting Sharing Water: Multipurpose of Reservoirs and Innovations, 4 - 11 June 2021, Marseille, France, https://cigb-icold2021.fr/en/

International Airfield and Highway Pavements Conference, June 6-9, 2021, Austin, Texas, USA, www.pavementsconference.org

MSL 2021 The 1st Mediterranean Symposium on Landslides SLOPE STABILITY PROBLEMS IN STIFF CLAYS AND FLYSCH FORMATIONS, 7-9 June 2021, Naples, Italy, https://medsymplandslides.wixsite.com/msl2021

6th Rock Mechanics& Tunneling Day - Rock mechanical aspects of the Railway Project Stuttgart –Ulm and other national and international projects, 10.06.2021, Rosengarten, Mannheim, Germany, www.felsmechanik.eu

5th Symposium of the Macedonian Association for Geotechnics "The problems associated with soft rocks in rock engineering", an ISRM Specialized Conference, 10-12.06.2021, Ohrid, North Macedonia, https://mag.net.mk/v-mag-symposium-28-30-5-2020

9th International Conference on Computational Methods for Coupled Problems in Science and Engineering (COUPLED PROBLEMS 2021), 13-16 June 2021, Sardinia, Italy, coupledproblems_sec@cimne.upc.edu

Rapid Excavation and Tunneling Conference RETC2021, June 13-16, 2021, Las Vegas, Nevada, USA, www.retc.org

Cities on Volcanoes 11 - Volcanoes and Society: environment, health and hazards, 14-18 June 2021, Heraklion, Crete, https://pcoconvin.eventsair.com/volcanoes11

International Scientific Conference
Doctrinal texts – achievements, importance and future in the protection of heritage
/90th anniversary of the Athens Charter/
12th edition, June 14-15, 2021, Florence. Italy
www.lifebeyondtourism.org/events/icomos-iscthe-ory-florence-2021

ISSUES OF THE CONFERENCE

In 1931, the *First International Congress of Architects and Technicians of Historic Monuments* was held in Athens. More than 100 delegates representing 22 countries participated in the Congress. The Congress, which lasted for 10 days provided an opportunity for a wide exchange of views and experiences on many aspects of the preservation of monuments. Almost 40 contributions were presented in Athens. The Congress adopted a document entitled *The Athens Charter for the Restoration of Historic Monuments*. This document can be considered as the first international text formulating conservation doctrine.

In 2021 the conservation community will celebrate the 90th anniversary of the adoption of the Athens Charter. This presents an opportunity for the international conservation community to once again discuss doctrinal texts in heritage protection. In view of global developments, socio-political, economic, climatic changes there are several pressing reasons to organize discussion on this topic.

The first reason is the growing importance of doctrinal texts. Doctrinal texts have long played an important role in protecting heritage, however, in recent years they have become increasingly more important and necessary. Conservation theory develops in response to the transformation of heritage and the needs of societies. Today, modernization pressures and social change are leading to ever deeper interference with historical objects and sites. Therefore, normative documents are increasingly necessary, which define the principles and limits of the handling of cultural heritage in contemporary conditions.

The second reason is the large number of doctrinal texts that have been created in recent decades. Today, the meaning of heritage is very large and diverse, and consequently the conditions for its protection are more complex and diverse. Therefore, the conservation theory is fragmented. As a result, the usefulness of universal doctrinal texts, which were normative for the entire protection of heritage, has decreased. Numerous new doctrinal texts have been created, which concern only specific groups of objects, regional heritage or selected conservation activities. In this situation, it is necessary to examine what kind of picture of discipline these texts create, or whether it loses consistency.

The third reason is the clear increasing focus of current conservation theory on the stakeholders. Many important doctrinal documents, which have been adopted by interna-tional organizations (UNESCO, ICOMOS International), very clearly emphasise the rights of stakeholders to define herit-age, forms of its protection and use. In practice, this leads to a weakening of the position of the conservation services and greater transformation of historical objects. It is therefore necessary to examine the current state of conservation theory as a result of the implementation of a stakeholder-centred approach to practice. Does current conservation theory strike the right balance between stakeholder rights and heritage rights?

Doctrinal texts are a recognized form of shaping conservation theory. ICOMOS is the world's most important international heritage protection organization, which is why it produces the most doctrinal texts that are distributed worldwide. Therefore, it is relevant that ICOMOS should have a debate on the contemporary state and prospects for the entire corpus of doctrinal documents in heritage protection.

AIMS AND THEMATIC SCOPE OF THE CONFERENCE

The aim of the conference ***Doctrinal texts – achievements, importance and future in the protection of heritage*** is a discussion on the key issues of doctrinal documents in heritage conservation that condition and specify the future of this discipline.

The aim of the conference is to take a comprehensive look at the current situation of doctrinal documents in heritage protection and thus create a basis for identifying the main threats, problems and proposals for heritage solutions.

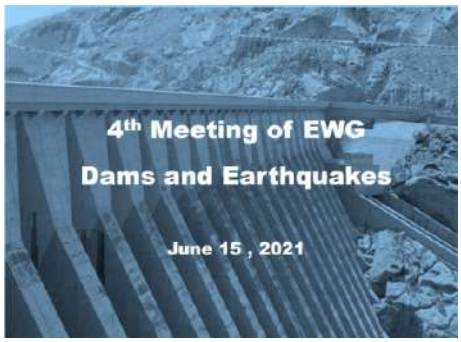
The aim of the conference is to articulate the problems and topics that can be discussed by the various bodies of ICOMOS.

The conference will address three groups of problems (in 3 sessions)

1. Contemporary conservation theory in the light of doctrinal documents – critical analysis of doctrinal texts
2. The importance and role of doctrinal texts in conservation practice - implementation of doctrinal texts into practice
3. Development of doctrinal texts – needs and proposals of new doctrinal texts

We invite all specialists who wish to take part in the discussion on the problems and future of doctrinal documents of heritage protection. We invite representatives of all the International Scientific Committees of ICOMOS and National Committees of ICOMOS. We invite all those involved in the theory and practice of heritage protection in all its aspects.

We hope that the conference will be a forum for exchanging views and shaping opinions for the different international environments of ICOMOS.



Joint meeting of ISSMGE TC201 and TC210, ICOLD TC E and TC LE "Dams and Levees: Particle Movements – Case Studies, Experiments, Theory", June 16-19, 2021, Budapest, Hungary, www.isc6-budapest.com

6th International Conference on Geotechnical and Geophysical Site Characterization "Toward synergy at site characterisation", June 16-19, 2021, Budapest, Hungary, www.isc6-budapest.com

EGRWSE 2020 - 3rd International Conference on Environmental Geotechnology, Recycled Waste Materials and Sustainable Engineering, 17-19 June 2021, Izmir, Turkey, www.egrwse2020.com

2nd ICPE 2021 The Second International Conference on Press-in Engineering, 19-21 June 2021, Kochi, Japan, https://icpe-ipa.org/

DFNE 2021 3rd International Conference on Discrete Fracture Network Engineering (in conjunction with ARMA 2021), June 23-25, Houston, Texas, USA, www.dfne2021.org

1st International Conference on Sustainability in Geotechnical Engineering, ICSGE, 27-30 June 2021, Lisboa, Portugal, http://icsge.lnec.pt/#

DFI Deep Mixing, 5-8 July 2020, TBD, Gdansk, Poland, www.dfi.org/DM2020

II International Seminar "Tailings and Waste Rock Disposal", July 12 – 14, 2021, Lima, Peru, www.geoingenieria.org.pe

7th ICRAGEE International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, 12-17 July 2021, Bengaluru, India, http://7icragee.org

AFRICA 2021 Water Storage and Hydropower Development for Africa, 13-15 July 2021, Lake Victoria, Uganda, www.hydropower-dams.com/africa-2021

GEOCHINA 2021 - 6th GeoChina International Conference Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solution, July 19 to 21, 2021, Nan-Chang, China, http://geochina2021.geoconf.org

PanAm Unsat 2021 3rd Pan-American Conference on Unsaturated Soils, 25-28 July 2021, Rio de Janeiro, Brazil, https://panamunsat2021.com

7th International Conference on Industrial and Hazardous Waste Management 27-30 July 2021, Chania, Crete, Greece, http://hwm-conferences.tuc.gr (online participation available)

ACE 2020 14th International Congress on Advances in Civil Engineering, 6-8 September 2021, Istanbul, Turkey, www.ace2020.org/en

XVIth International Congress AFTES 2021 Underground, a space for innovation, 6 to 8 September 2021, www.aftes2020.com

COMPLAS 2021 XVI International Conference on Computational Plasticity, Fundamentals and Applications, 7-10 September 2021, Barcelona, Spain, https://congress.cimne.com/complas2021/frontal/default.asp

RMEGV 2021 - 5th International Workshop on Rock Mechanics and Engineering Geology in Volcanic Fields, 9÷11 September 2021, Fukuoka, Japan, https://ec-convention.com/rmegv2021

International Conference on Textile Composites and Inflatable Structures (MEMBRANES 2021), 13-15 September 2021, Munich, Germany, https://congress.cimne.com/membranes2021/frontal/default.asp

EUROGEO WARSAW 2020 7th European Geosynthetics Congress, 19-22 September 2021, Warsaw, Poland, www.eurogeo7.org

37th General Assembly of the European Seismological Commission, 19-24 September 2021, Corfu, Greece, www.escgreece2020.eu

EUROCK TORINO 2021 - ISRM European Rock Mechanics Symposium Rock Mechanics and Rock Engineering from theory to practice, 20-25 September 2021, Torino, Italy, http://eurock2021.com

This British Tunnelling Society "BTS 2020" Conference and Exhibition, Sept 30th - Oct 1st, 2021, London, United Kingdom, www.btsconference.com

Virtual EUROENGEO 3RD EUROPEAN REGIONAL CONFERENCE OF IAEG, 7 - 10 October 2021, Athens, Greece, www.euroengeo2020.org

10th International Conference on Scour and Erosion (ICSE-10), October 17-20, 2021, Arlington, Virginia, USA, www.engr.psu.edu/xiao/ICSE-10 Call for abstract.pdf

3rd International Symposium on Coupled Phenomena in Environmental Geotechnics, 20-22 October 2021, Kyoto, Japan, https://cpeg2020.org

ARMS11 11th Asian Rock Mechanics Symposium, Challenges and Opportunities in Rock Mechanics, 21-25 October 2021, Beijing, China, www.arms11.com

HYDRO 2021 Roles of hydro in the global recovery, 25-27 October 2021, Strasbourg, France, www.hydropower-dams.com/hydro-2021

EURO:TUN 2021 Computational Methods and Information Models in Tunneling, October 27th - 29th, 2021, Bochum, Germany, http://eurotun2021.rub.de

GFAC 2021 International Conference "Geotechnics fundamentals and applications in construction: investigations, design, technologies", October 27–29, 2021, Saint Petersburg, Russia https://gfac.spbgasu.ru

Emerging Technologies and Applications for Green Infrastructure, 28-29 October 2021, Ha Long, Vietnam, https://cigos2021.sciencesconf.org

5TH World Landslide Forum Implementation and Monitoring the USDR-ICL Sendai Partnerships 2015-2015, 2-6 November 2021, Kyoto, Japan, http://wlf5.iplhq.org

ISFOG 2020 4th International Symposium on Frontiers in Offshore Geotechnics, 8 – 11 November 2021, Austin, United States, www.isfog2020.org

2021 GEOASIA7 - 7th Asian Regional Conference on International Geosynthetics Society, November 22-26, 2021, Taipei, Taiwan, www.geoasia7.org

ICGE – Colombo – 2020 3rd International Conference in Geotechnical Engineering, 6-7 December 2021, Colombo, Sri Lanka, http://icgecolombo.org/2020/index.php

2nd International Conference TMM-CH Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage - Rebranding The World In Crisis Through Culture, 12-15 December, 2021 Athens, Greece https://tmm-ch.com/

GeoAfrica 2021 - 4th African Regional Conference on Geosynthetics Geosynthetics in Sustainable Infrastructures and Mega Projects, 21-24 February 2022, Cairo, Egypt, https://geoafrica2021.org

ICEGT-2020 2nd International Conference on Energy Geotechnics, 10-13 April 2022, La Jolla, California, USA, https://icegt-2020.eng.ucsd.edu/home

WTC 2022 World Tunnel Congress 2022 - Underground solutions for a world in change, 22-28 April 2022, Copenhagen, Denmark, www.wtc2021.dk

SYDNEY 7iYGEC 2021 7th International Young Geotechnical Engineers Conference A Geotechnical Discovery Down Under, 29 April - 1 May 2022, Sydney, Australia, http://icsmge2021.org/7iygec

SYDNEY ICSMGE 2021 20th International Conference on Soil Mechanics and Geotechnical Engineering, 1–5 May 2022, Sydney, Australia, www.icsgme2021.org

LARMS 2021 – IX Latin American Rock Mechanics Symposium Challenges in rock mechanics: towards a sustainable development of infrastructure, 15 – 18 May 2022, Asuncion, Paraguay, https://larms2021.com

CPT'22 5th International Symposium on Cone Penetration Testing, 8-10 June 2022, Bologna, Italy, http://cpt22.org

3rd European Conference on Earthquake Engineering and Seismology (3ECEES), 19-24 June 2022, Bucharest, Romania, https://3ecees.ro

9th International Congress on Environmental Geotechnics
Highlighting the role of Environmental Geotechnics in Addressing Global Grand Challenges
26-29 June 2022, Chania, Crete island, Greece
www.iceg2022.org

The 9th International Congress on Environmental Geotechnics is part of the well established series of ICEG. This conference will be held on an outstanding resort in the town of Chania of the island of Crete in Greece. The theme of the conference is "Highlighting the role of Environmental Geotechnics in Addressing Global Grand Challenges" and will highlight the leadership role of Geoenvironmental Engineers play on tackling our society's grand challenges.

Contact Information

- Contact person: Dr. Rallis Kourkoulis
- Email: rallisko@grid-engineers.com

IS-Cambridge 2020 10th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, 27 - 29 June 2022, Cambridge, United Kingdom, www.is-cambridge2020.eng.cam.ac.uk

UNSAT2022
8th International Conference on Unsaturated Soils
June or September 2022, Milos island, Greece

ICONHIC2022: THE STEP FORWARD - 3rd International Conference on Natural Hazards & Infrastructure, 5 – 7 July 2022, Athens, GREECE, https://iconhic.com/2021

Eurock 2022

Rock and Fracture Mechanics in Rock Engineering and Mining
12÷15 September 2022, Helsinki, Finland
www.ril.fi/en/events/eurock-2022.html

Themes

- Rock mass Characterization
- Geophysics in rock mechanics
- Mechanics of rock joints
- Jointed rock mass behaviour
- Rock support, probability based design
- Rock stress measurements
- Constitutive modelling of rock
- Rock drilling
- Blast induced fractures
- Rock engineering and mining education
- Geological disposal of spent nuclear fuel
- Recent advances in rock mechanics research
- Field and laboratory investigations
- Case studies

Contact Person: Lauri Uotinen
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6th Australasian Ground Control in Mining Conference – AusRock 2022
17 – 19 September 2022, Melbourne, Australia

Organizer: UNSW Sydney, AusIMM
Contact Person: Ismet Cambulat
E-mail: icambulat@unsw.edu.au

28th European Young Geotechnical Engineers Conference and Geogames, 17 – 19 September 2022, Moscow, Russia, https://www.eygec28.com/?

11th International Conference on Stress Wave Theory and Design and Testing Methods for Deep Foundations, 20 - 23 September 2022, De Doelen, Rotterdam, The Netherlands, https://www.kivi.nl/afdelingen/geotechniek/stress-wave-conference-2022

LARMS 2022

IX Latin American Congress on Rock Mechanics, Rock Testing and Site Characterization

an ISRM International Symposium
16-19 October 2022, Asuncion, Paraguay

Symposium Themes

- Site characterization,
- Rock mass properties,
- Rock mass classification,
- Foundations,
- Slopes,
- Tunnels,
- Soft Rock,
- Shotcrete

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AusRock 2022

6th Australasian Ground Control in Mining Conference –an ISRM Regional Symposium
07 -09 November 2022, Melbourne, Australia

Organizer: UNSW Sydney, AusIMM
Contact Person: Ismet Cambulat
E-mail: icambulat@unsw.edu.au

88th ICOLD Annual Meeting & Symposium on Sustainable Development of Dams and River Basins, April 2023, New Delhi, India, https://www.icold2020.org

XII ICG - 12th International Conference on Geosynthetics, September 17 – 21, 2023, Rome, Italy, www.12icg-roma.org

15th ISRM

International Congress in Rock Mechanics
9÷14 October 2023, Salzburg, Austria

Organizer: Austrian Society for Geomechanics
Contact Person: Prof. Wulf Schubert
E-mail: salzburg@oegg.at

ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

Düzce Zonguldak: a spectacular retaining wall failure on a highway in Turkey

On 26 March 2021 a spectacular retaining slope failure occurred on a highway at Düzce Zonguldak in Turkey. I haven't seen any images of this failure in the UK media, which is a shame as it is an unusual event. Haber Golkoy has this image of the landslide:-

The highway slope failure at Düzce Zonguldak in Turkey on 26 March 2021

According to the news reports the slope failed overnight. No-one was hurt. Unsurprisingly, the road is now closed, with traffic being diverted onto local roads. This view, from an image posted by Cumhuriyet, provides a better idea of the materials involved:-

A close up view of the highway slope failure at Düzce Zonguldak in Turkey on 26 March 2021

It is interesting that the road has been built across a topographic depression on an embankment made from fill. I am no expert on retaining structures – is this a mechanically stabilised retaining wall? [In the comments below Fabien Peyrel has confirmed that this is a Mechanically stabilized earth (MSE or reinforced soil) structure]. The wall has slumped spectacularly.

Scenarios for this event here could include failure through the foundation of the structure (a bearing capacity failure) and/or a build up of excessive pore water pressures in the fill causing a fillslope failure. The latter would imply inadequate drainage of the fill, either because of poor design or construction, or because of poor maintenance. Again, I would be very interested in the views of others in the comments.

The news reports suggest that the road at Düzce Zonguldak was opened in 2012. The highway was reportedly constructed by Limak Holding.

Clearly reconstruction of this highway is going to be a substantial task. If the failure is the result of a design, construction or maintenance error then other sections of the road may well be at risk too.

(Dave Petley / THE LANDSLIDE BLOG, 1 April 2021, https://blogs.agu.org/landslideblog/2021/04/01/duzce-zonguldak-1/)

Neustift in Austria: boulder vs house, the boulder won

In Neustift in Austria, a 4 metre high boulder struck a house on 2 April 2021 having detached from an adjacent slope. This image below, from Tyrol ORF, gives an idea of the scale of the event:-

The boulder that struck a house in Neustift in Austria.

The image below, shows the track of the boulder prior to striking the house:-

The track of the boulder that struck a house in Neustift in Austria.

Note that the boulder has crashed through two flexible rock-fall barriers:-

Destroyed flexible barriers along the track of the boulder that struck a house in Neustift in Austria.

Clearly, barriers on this scale were not designed to catch a boulder of the scale of the one that struck the house. Fortunately there were no casualties in this event.

The boulder has a very strong tabular shape (like a very large, flattened pebble of the type that you could skim on flat water). The track, and the orientation of the boulder in the house, suggest that the rock was rotating along its short axis, much like a wheel. It also appears that the boulder was losing contact with the surface at times (see the second image), thus rolling and bouncing down the slope. If a tabular boulder gets into this configuration of movement it is both stable and highly mobile, allowing the long runout across the field before striking the house.

The adjacent properties have been temporarily evacuated whilst a 3 m high berm is being built to provide short term protection. The house in Neustift that was struck by the boulder will need extensive reconstruction:-

The interior of the house struck by the boulder in Neustift in Austria.

The simple necessity of removing the boulder is going to be a challenge given both the scale of the rock and the likelihood of significant structural damage to the corner of the property.

This is the latest of several of these events in recent years. I'm reminded of Rocky, the famous boulder from the 2011 Christchurch earthquakes.

(Dave Petley / THE LANDSLIDE BLOG, 5 April 2021, https://blogs.agu.org/landslideblog/2021/04/05/neustift-in-austria-boulder-vs-house-the-boulder-won)

This one from 2014, Italy. One cut through the property and another just stopped short

https://twitter.com/Vedicland/status/1379073752189652998

The complex politics of managing coal waste tip stability in South Wales

The valleys of South Wales have one of the most complex landslide settings in the UK. It is a landscape that has a great deal of natural instability, much of it relict. However, many slopes continue to move, sometimes causing substantial levels of disruption. On top of this is imprinted the effects of decades of coal extraction, which led to increased instability. In some cases existing landslides were reactivated. And finally, and most significantly, poor coal waste management practises led to the creation of thousands of spoil tips, some of which had substantial stability problems. The worst example is of course the appalling 1966 Aberfan disaster, but that case was just one of many spoil tip landslides.

Google Earth image of the coal waste tips at Tylorstown in South Wales. Note the large conical tip at the top of the hill and the failed tip in the lower left corner.

Coal mining has now ceased, and many of the most dangerous spoil tips have been removed. However, the landscape remains dotted with many legacy waste piles, often located high on the valley walls. These have been mostly stable in recent decades, but in February 2020 it became clear that the beast was waking from its slumbers. Heavy rainfall triggered a large failure in a coal spoil tip at Tylorstown. And then in December a further failure occurred at Wattstown.

It is now recognised that there is a major problem. There are thought to be about 2,100 spoil tips left in the valleys of South Wales. Around 300 of these are considered to be high risk. Perhaps surprisingly, only 40 of these are managed by the Coal Authority, the governmental nod with responsibility for (amongst other things) the management of historic liability issues, including polluted water, subsidence and surface hazards associated with past mining activity. The remainder are owned by a range of bodies, including local authorities. Perhaps surprisingly, the majority are privately owned.

The FT has a really good article about the complex politics that surround the management of the coal waste tip stability hazard. It notes that the likely financial cost of dealing with the hazard is very substantial – the Tylorstown tip alone might cost £10 million to remediate. The total bill might be in the order of £500 million – and experience tells us that these costs tend to balloon once the work commences.

Until recently the UK Government position has been that this is a problem for the Welsh Government, but the scale of the threat means that it is likely to be beyond its means. Cash strapped local authorities and private land owners will not have the resources. The article notes that there is a strong argument that the coal was mined in the national interest, such that the costs should be carried by the whole of the United Kingdom.

Strangely, the slow motion horror show that is Brexit may play a key role in how this plays out. In Scotland, Brexit has turbocharged the move towards independence, threatening the historic union. This is now spilling over to Wales, where the profile of independence is rising. Boris Johnson is the Prime Minister from the Conservative and Unionist Party; the gathering momentum for independence is not a good look. So, the article speculates, the UK Government might have to step in to cover the costs of mitigating the spoil tip hazard as a sweetener to the electorate in Wales.

Landslide hazard is often viewed as a physical process, managed through good engineering geology and high quality engineering. The reality is that the scale of the threat means that politics is often at least as important of engineering. In the case of South Wales, the complex politics might be the key that unlocks the funding needed to manage the threats posed by the coal waste tips.

(Dave Petley / THE LANDSLIDE BLOG, 7 April 2021, https://blogs.agu.org/landslideblog/2021/04/07/the-complex-politics-of-managing-coal-waste-tip-stability-in-south-wales)

Culluchaca: a large landslide on 7 April 2021 in Peru

On 7 April 2021 a large failure occurred close to the village of Culluchaca in Huari province of the Áncash region of Peru. The landslide did not claim any lives but caused serious damage to about 1 km of National Road 14a:-

The aftermath of the landslide close to Culluchaca in Peru.

The location of the landslide appears to be -9.301534° -77.008174°. This is a Google Earth oblique view of the site:

Google Earth view of the site of the landslide close to Culluchaca in Peru.

The image shows an existing large failure at this site. Note also the very clear tension cracks located above the existing crest of the landslide. I suspect that a large block delineated by these cracks has failed. The image below shows the aftermath of the landslide:-

Note the very extensive scale of the landslide in the image above. It is clear that a large volume has failed.

The aftermath of the landslide close to Culluchaca in Peru.

According to a news report in Áncash Noticias (in Spanish), the population of the village of Culluchaca have had to be evacuated because of the risk. In addition the landslide has disrupted the electricity network supply the districts of Huacachi, Anra, Uco, Rapayán, Paucas and Huacchis in the province of Huari, and some parts of the province of Antonio Raimondi and Huamalies.

There is a video that captures some of the failure and the aftermath on Youtube: https://www.youtube.com/watch?v=gJWlWs6ijyM&t=12s

Clearly reinstatement of the road will be important, but this will not be possible until the landslide has stabilised again. It will not be a straightforward problem to solve. Fortunately the images above suggest that the river is probably not blocked by the landslide, at present at least.

(Dave Petley / THE LANDSLIDE BLOG, 11 April 2021, https://blogs.agu.org/landslideblog/2021/04/11/culluchaca-1)

The interesting morphology of the Culluchaca landslide in Peru

After posting yesterday about the Culluchaca landslide in Peru, I spent some time looking at the morphology of the site using the Google Earth Imagery. As a reminder, this is what the Google Earth images show. The image was collected in July 2019:-

The interesting features of this landslide lie above the crest of the slide shown above. The image below shows that area, on this occasion looking square onto the landslide:-

Google Earth view of the site of the landslide close to Culluchaca in Peru.

Google Earth view of the crest of the landslide close to Culluchaca in Peru.

The image appears to show two arrays of tension cracks. The first set, marked with A, are about 50 metres back from the landslide crown. But there is another set, marked with B, that are probably less well developed. These are about 150 metres back from the landslide crown, indicating a very large instability.

Perhaps even more interesting is the set of features further across the slope. The image below shows the morphology of this area. I've left the other markers in place for reference:-

Google Earth view of features at the crest of the landslide close to Culluchaca in Peru.

Running across the slope parallel to the crest is an array of linear depressions, some of which are large and extensive. Upslope from here is a ridge with extensive bouldery deposits, which is probably a scarp.

The most likely explanation for these features at that this is the site of a *deep-seated gravitational deformation (DSGD)*, defined as *"a gravity-induced process affecting large portions of slopes evolving over very long periods of time. A DGSD may displace rock volumes of up to hundreds of millions of cubic meters, with thicknesses of up to a few hundred meters."*

DSDGs are very large, slow creeping failures in rock masses, common in high mountain areas. I wrote about an example in Italy in 2019. They typically generate arrays of parallel scarps and troughs high up on the hillside.

Thus, the failure of the Culluchaca landslide on 7 April 2021 is probably only a small part of the unstable mass on this slope. However, that does not necessarily mean that further collapses are likely in the short term – DSGDs creep for hundreds and even thousands of years.

I should note that an alternative explanation for these features in this landscape as an active fault. This possibility cannot be precluded without further investigation.

(Dave Petley / THE LANDSLIDE BLOG, 12 April 2021, https://blogs.agu.org/landslideblog/2021/04/12/culluchaca-landslide-2)

Large coastal landslide at Nefyn Bay in north Wales, U.K.

A large coastal landslide took place at Nefyn Bay in north Wales, U.K. on April 19, 2021. The event was captured on camera by Amanda Stubbs who was there when it started.

The landslide happened on Nefyn's coastline in Gwynedd, taking a large part of the garden on the cliff above. It's at least 40 m (131 feet) wide, according to eyewitnesses.

The police secured the area and advised the public to avoid it until further notice.

This area -- listed as a 'subsidence hazard zone' -- is known for its coastal erosion, with a history of large and deadly landslides, including rotational failures, flows, falls, and debris slides.

Dr. Dave Petley of The Landslide Blog said the landslide is interesting for its timing during an unusually dry period for the time of the year and for its quite long runoff.

"It starts as a small retrogressive slump on the margin of what becomes the main slide. This destabilizes the main mass, which fails through a strongly rotational mechanism. After failure, the mass runs across the beach as a high mobility earthflow," Petley said.

"This landslide has received some attention in the UK, but strangely the most interesting element has not really received much publicity. This is that the landslide was captured on video by a woman, Amanda Stubbs, who was standing at the toe."

Amanda took the video just about 180 meters (200 yards) from her holiday home. "Although I've seen the aftermath of many small landslides I have never witnessed one of this scale first hand," she said. https://www.youtube.com/watch?v=jQG152DZDFE

"It was just frightening," Sue Cookson told the BBC. "There were a few people around and we just made sure there was nobody under the landslip because we thought there could be."

The noise was quite incredible, Cookson said.

(Teo Blašković / THE WATCHERS, April 20, 2021, https://watchers.news/2021/04/20/landslide-nefyn-bay-north-wales-april-202)

The 19 April 2021 coastal landslide at Nefyn Bay in North Wales

On 19 April 2021 a really interesting coastal landslide occurred at Nefyn Bay in North Wales. The BBC has some good imagery of the aftermath:-

The 19 April 2021 coastal landslide at Nefyn Bay in North Wales

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This landslide is interesting for its timing – the UK is having a spell of unusually dry weather for April – and for its runout, which is quite long.

This landslide has received some attention in the UK, but strangely the most interesting element has not really received much publicity. This is that the landslide was captured on video by a woman, Amanda Stubbs, who was standing at the toe. It is brilliant. You should be able to see it at https://www.youtube.com/watch?v=jQG152DZDFE

The landslide starts as a small retrogressive slump on the margin of what becomes the main slide. This destabilises the main mass, which fails through a strongly rotational mechanism. After failure the mass runs across the beach as a high mobility earthflow.

There is some excellent drone imagery of the aftermath:-

The imagery shows the multiple scars of previous landslides on this section of coast, so this failure comes as no surprise. The British Geological Survey (BGS) have a page dedicated to coastal landslides at Nefyn Bay, based on work undertaken after a fatal landslide on this section of coast in 2001. There is also a paper online (Jenkins *et al.* 2007 – one of the authors is my former PhD student Andy Gibson) that describes the nature of the landslides at the site and the evolution of the hazard. The landslides occur in glacial deposits that are eroded by the sea, exacerbated by sand layers overlying a low permeability clay.

Reference

Jenkins, G.O.; Gibson, A.D.; Humpage, A.J.. 2007. Climate change and evolution of landslide hazard at Nefyn Bay, North Wales. In: McInnes, Robin, (ed.) *Landslides and climate change: challenges and solutions. Proceedings of the International Conference on Landslides and Climate Change.* Taylor and Francis, 113-119.

Nefyn beach landslide: People warned to keep away

A major landslide at a beach in north Wales has prompted warnings for people to stay away.

The cliff fall, which eyewitnesses say is up to 40m (131ft) wide, happened on Nefyn's coastline in Gwynedd.

The landslide happened in front of homes at Nefyn beach

Neighbours say the house that lost a large part of its garden is a second home

Joan Coppin, who lives near the beach, said: "It's taken land from the bottom of holiday homes on Rhodfar Mor - we have got local people to the right of those and they are in quite a precarious place, I would say.

"Us locals don't go there when the tide is coming in. The whole of the area - about two-and-a-half miles - has coastal erosion. We have had big landslides before."

The landslide was reported to police on Monday afternoon

In 2001, Shirley Race, 58, died and her husband Donald, 63, was seriously injured in Nefyn when a landslide engulfed their car, sweeping it over a cliff and into the sea.

The British Geological Survey (BGS) lists Nefyn as being in a "subsidence hazard zone".

The coastal area has a surface geology of weak, superficial drift deposits of clay, silt, sand and gravel.

One house has lost a large area of its garden

The BGS has said there was "a variety of landslide types within Nefyn Bay including rotational failures, flows, falls and debris slides.

"The slopes are covered in weathered debris and this is particularly susceptible to shallow landsliding, especially when saturated by water."

When asked if people living in Nefyn should be worried, engineering geologist for the BGS Ashley Patton said: "I wouldn't want to scare anyone but of course, when you see events like this and of this scale, you can't help but think 'is that area of the cliff next'?

"Of course that happens all along that coastline, so there is the potential anywhere could go."

Emergency services and utility companies are securing the scene

(April 20, 2021, https://www.bbc.com/news/uk-wales-56799238)

Massive cliff collapse in Jurassic Coast, UK

A cliff collapse that occurred in England's Jurassic Coast is considered to be the largest to hit the region in 60 years.

The landslide struck in mid-April near Weymouth, a town located in Dorset County on the Jurassic Coast. The Jurassic Coast stretches for more than 150 kilometers in southern England and is characterized by its unique rock formations that cover 3 geological periods (Cretaceous, Triassic and Jurassic). Fossil remains have been found from different areas. Due to its importance, the Jurassic Coast has been declared as a World Heritage Site since 2001.

Landslides at the Jurassic Coast occur due to erosion and weathering processes that are accelerated in coastal regions. As a result, cliff collapses are usual. "Wind, waves and weather all act on the cliffs, which can fall and slip without warning. So stay safe – keep away from the tops or bases of the cliffs and stay off slip material on the beach," Dorset council tweeted occasioned by the current failure.

The collapse struck in a sandstone cliff and its failure mechanism resembles a rotational slump. Slumps occur along a circular or near-circular failure surface that rotates around an axis parallel to the slope. They are associated with shear failure of the material or movement along a layer of higher strength. Officials stated that about 4.000 tons of material gave way and have been deposited downwards with 300 meters of the cliff being impacted. Fortunately, there were no victims as the failure occurred over the night and no one was at the beach.

The area had recently experienced mixed weather conditions but geologists believe the failure was entirely associated with the erosion processes that take place and deteriorate the stability of the slope.

The cliff was found to be prone to further landsliding with subsequent (smaller) failures occurring. A team of experts visited the site to evaluate the conditions and decide about further actions. The area is being currently monitored with officials focusing on new cracks that emerged on the cliff after the collapse.

According to reports, there is a substantial crack on the west side of the cliff that will probably trigger new collapses in the future. A roadway running across the coastline was re-routed and people were advised to avoid coming close to the cliff.

In August 2020, a cliff collapsed in the central part of the Jurassic Coast as a result of both erosion processes and heavy rainfalls. That failure was smaller than the current one (about 9,000 tons of debris) but it occurred in a hazardous area visited daily by people. Fortunately, no one was swept away by the debris. Later that year, another rockfall struck near the area of the current incident.

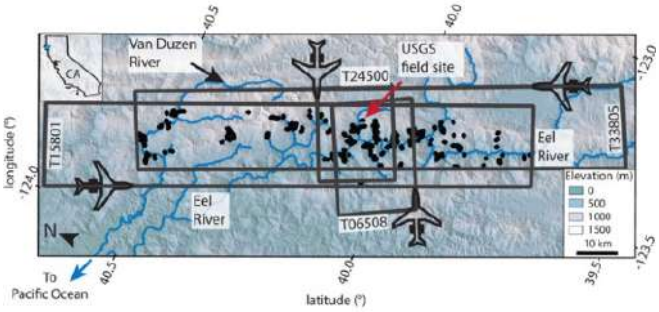
Click below to watch a video and some stunning photographs retrieved from the site of the cliff collapse.

Guardian News https://www.youtube.com/watch?v=_Uz-znbnxVIk

(GeoEngineer, Apr, 12, 2021, https://www.geoengineer.org/news/massive-cliff-collapse-in-jurassic-coast-uk)

Thickness and Strength of Slow-moving Landslides Revealed

Hundreds of slow-moving landslides' deformation patterns were inverted to obtain their thickness and frictional strength, revealing that larger landslides are weaker and thinner than smaller ones



Map of the northern California Coast Ranges study site. Black polygons outline the active landslides analyzed in this study. Elevation (in meters) is shown by green to white color gradient. Black boxes show the left looking UAVSAR swaths and corresponding track numbers with airplanes showing flight direction. Red arrow shows the location of a U.S. Geological Survey (USGS) landslide field site. Blue lines show major rivers and some tributaries in landslide areas. Inset shows a map of California with a star corresponding to the study site. Credit: Handwerger et al. [2021], Figure 1

The largest and fastest slow-moving landslides can cause substantial hazard to infrastructure and communities. Nevertheless, assessing the thickness, mechanical state, and displacement rate of such landslides is very difficult.

Handwerger et al. [2021] use radar measurements obtained from an Uninhabited Aerial Vehicle to measure the 3D velocity over more than a hundred landslides in Northern Califor-

nia. Further, they used the displacement pattern to infer the landslide thickness and strength.

They found that these slow landslides had geometries similar to rapidly failing landslides, and also that beyond a certain size, large landslides seemed to grow only in area and not grow thicker. Last, and more puzzling, they found that larger landslides are weaker. To explain this, the authors propose that larger landslides have more chance to incorporate the very weak portion of the heterogeneous local lithology.

Citation: Handwerger, A. L., Booth, A. M., Huang, M.-H., & Fielding, E. J. [2021]. Inferring the subsurface geometry and strength of slow-moving landslides using 3-D velocity measurements from the NASA/JPL UAVSAR. Journal of Geophysical Research: Earth Surface*, 126, e2020JF005898. https://doi.org/10.1029/2020JF005898*

(Odin Marc, Associate Editor / *JGR: Earth Surface*, 22 April 2021, https://eos.org/editor-highlights/thickness-and-strength-of-slow-moving-landslides-revealed#.YIF6GQx6WHw.twitter)

Inferring the Subsurface Geometry and Strength of Slow-Moving Landslides Using 3-D Velocity Measurements From the NASA/JPL UAVSAR

Alexander L. Handwerger, Adam M. Booth, Mong-Han Huang, Eric J. Fielding

Abstract

The hazardous impact and erosive potential of slow-moving landslides depends on landslide properties including velocity, size, and frequency of occurrence. However, constraints on size, in particular, subsurface geometry, are lacking because these types of landslides rarely fully evacuate material to create measurable hillslope scars. Here, we use pixel offset tracking with data from the NASA/JPL Uninhabited Aerial Vehicle Synthetic Aperture Radar to measure the three-dimensional surface deformation of 134 slow-moving land-slides in the northern California Coast Ranges. We apply vol-ume conservation to infer the actively deforming thickness, volume, geometric scaling, and frictional strength of each landslide. These landslides move at average rates between ~0.1–2 m/yr and have active areas of ~6.10×10^3–2.35×10^6 m^2, inferred mean thicknesses of ~1.1–25 m, and volumes of ~7.01×10^3–9.75×10^6 m^3. The best fit volume-area geometric scaling exponent is $\gamma \sim 1.2$–1.5, indicating that these landslides fall between typical soil and bedrock landslide scaling. A rollover in the scaling relationship suggests that the largest landslide complexes in our data set become large primarily by increasing in area rather than thickness. In addition, the slow-moving landslides display scale-dependent frictional strength, such that large landslide tend to be weaker than small landslides. This decrease in frictional strength with landslide size is likely because larger landslides are composed of higher proportions of weak ma-terial. Our work shows how state of the art remote sensing techniques can be used to better understand landslide pro-cesses and quantify their contribution to landscape evolution and hazards to human safety.

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020JF005898

The 21 October 1993 Pantai Remis landslide in Malaysia: an upscaled video

Early in the days of this blog I posted about an extraordinary video of a landslide in Malaysia. Almost thirteen years on this video remains hard to beat. The recording in question shows the 21 October 1993 Pantai Remis landslide in Malaysia.

This was a very unusual failure that occurred in an open cast tin mine near to the coast. Mining operations ventured too close to the sea, eventually triggering a collapse of the quarry walls. Ultimately the sea flooded the mine, creating a new cove that is still visible on Google Earth.

The video captures the collapse sequence of the Pantai Remis landslide. The failures occurred as massive rotational slides that transition into highly mobile flows through liquefaction. The mine quarry flooded catastrophically and completely. But the drawback of this video was that the quality was poor.

However, Jaren Christopher Kelley has posted a new version of the video to Youtube. This has been upscaled from the original, greatly improving the quality. You should be able to see the video below:

https://www.youtube.com/watch?v=3EXyyq-2RnA

The image below shows the first rotational failure at Pantai Remis in action:-

One of the rotational failures at the 1993 Pantai Remis landslide in Malaysia.

One of the extraordinary aspects of this video is that it is timestamped, which allows a reconstruction of the sequence of events.

This video remains hard to beat, and the new version makes it much more usable.

(Dave Petley / THE LANDSLIDE BLOG, 26 April 2021, https://blogs.agu.org/landslideblog/2021/04/26/pantai-remis)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ & ΑΝΤΙΣΕΙΣΜΙΚΗ ΜΗΧΑΝΙΚΗ

Scientists finally know how big earthquakes start: with many smaller ones

The vast majority of earthquakes we feel come soon after smaller ones, according to new research that offers new insights into how seismology works.

The finding offers unprecedented insight into what happens before moderate and large earthquakes—and scientists are finding that the vast majority of them occur after smaller earthquakes start rippling underneath the ground, sometimes days or even weeks before the main shock.

"One of the biggest questions in earthquake seismology is how earthquakes get started," said the study's lead author, Daniel Trugman, seismologist at Los Alamos National Laboratory. "We're finding that most, if not all, of (significant) earthquakes are preceded by foreshocks that we can detect" with a new computing technique.

Previously, scientists observed that only half of all moderate quakes had precursor smaller events. Now, this new study of earthquakes in Southern California of at least magnitude 4 between 2008 and 2017 finds that at least 72% of them had earlier, smaller quakes.

"Elevated foreshock activity is pervasive in Southern California," the study concluded.

"It is surprising," study coauthor Zachary Ross, Caltech assistant professor of geophysics, said. "It's important for understanding the physics of earthquakes. Are they silent until this big event? Or is there a weakening process of the fault, or some evidence that the fault is changing before this larger event?"

The study shows how the answer is likely the latter explanation.

The discovery now gives scientists a better understanding about how most earthquakes generate. Understanding that even moderate quakes probably occur after a series of little ones gives added weight to the idea that earthquake sequences can grow, not unlike the spreading epidemic of a disease. In fact, the study shows the foreshock sequences ranged from starting 3 days to 35 days ahead of the mainshock.

The finding doesn't mean we should all suddenly be worried about small quakes. Statistically speaking, only 5% of earthquakes are followed up by something worse.

It also doesn't mean researchers are any closer to predicting the exact times and locations of big earthquakes, something widely seen as impossible.

"The vast majority of time that you have an earthquake, even if you see anomalous activity start up, it's going to die down on its own—that's most of the time," Ross said.

But understanding how quakes get bigger can only help scientists get better at aftershock forecasting. That would help the public understand when there's a greater risk, like when the chance of a large quake rises from a background risk of 1-in-10,000 odds to 1-in-1,000 odds based on a previous quake.

"We are definitely moving toward forecasting that is statistical in nature," Trugman said.

The discovery could also help improve the speed of earthquake early warning systems, Ross said. If the computer has detected microquakes close to a major fault, and knows that most major quakes are preceded by smaller foreshocks, that can help speed up the decision by the system to issue a warning in the early moments after an earthquake has begun rupturing along a fault.

The breakthrough in the study, published in the journal Geophysical Research Letters several weeks ago, was only made possible by the discovery of a new technique to find very small earthquakes—quakes as small as magnitudes 0 and 1, and some as small as magnitude negative 2.

But detecting these microquakes is difficult to do. Currently, it can't be done in real time, and can only be done by feeding past quakes into a supercomputer, which takes a couple of weeks.

Having a higher-definition look at earthquakes in Southern California suddenly allowed scientists to detect many foreshocks that had been invisible previously.

"This new information is coming from the tiniest magnitude events that were basically invisible before," Ross said.

For the new study, Trugman and Ross decided to focus on 46 of the largest quakes in Southern California between 2008 and 2017 (while excluding those that were aftershocks of other larger events). They found that 33 of the 46 earthquakes had a statistically significant jump in foreshocks compared to the normal rate of earthquakes for that area.

They discovered a particularly lengthy foreshock sequence preceding the magnitude 5.1 La Habra earthquake of March 2014. There were foreshocks in the magnitude 0 and 1 range as early as 17 days ahead of the mainshock.

The 2010 Easter Sunday magnitude 7.2 earthquake widely felt in Southern California was not included in the analysis, since its epicenter was in Baja California. But that earthquake was preceded by a notable foreshock sequence.

The scientists could not determine a specific pattern to the foreshocks that would lead to a magnitude 4 or greater quake. Sometimes, it would appear as a burst of quakes near what would become the mainshock epicenter days or hours later. Other times, it would appear as a widespread increase in the earthquake rate in the general area before the mainshock.

They also found that shallower mainshocks tended to have more foreshocks, as do areas with higher heat flow, such as areas around the Coso Volcanic Field and the Salton Sea, which are warmed by magma.

The results help resolve a long mystery earthquake scientists couldn't explain before. In lab experiments where scientists would simulate earthquakes with sensitive equipment, there would always be small earthquakes that came before the main quake. "It's never just silent until the final failure," Ross said of the lab earthquakes.

The results suggest that it's possible that all moderate and large quakes are preceded by something smaller, but getting to that conclusion would require more studies.

"It's hard to imagine this huge fault that stays completely silent until a single point just happens to start failing," Ross said. "Physically, that seems a little difficult to imagine."

(Rong-Gong Lin Ii / PHYS ORG, August 20, 2019, https://phys.org/news/2019-08-scientists-big-earthquakes-smaller.html)

A 'ground-breaking' solution to quake impact

University of Technology Sydney researchers have developed a solution to protect buildings sitting on deep foundations from earthquakes resulting in surface fault ruptures. Their findings show a composite foundation system using inexpensive polymer materials can significantly improve the safety of infrastructure and substantially decrease fatality and damage due to large ground deformations.

Aerial view of a more than 30km long surface rupture observed in Meckering Western Australia in 1968 as a result of 6.6 magnitude earthquake.

Surface rupturing during earthquakes is a significant risk to any structure that is built across a fault zone that may be active, in addition to any risk from ground shaking. Surface rupture can affect large areas of land, and it can damage all structures in the vicinity of the fracture. Although current seismic codes restrict the construction in the vicinity of active tectonic faults, finding the exact location of fault outcrop is often difficult.

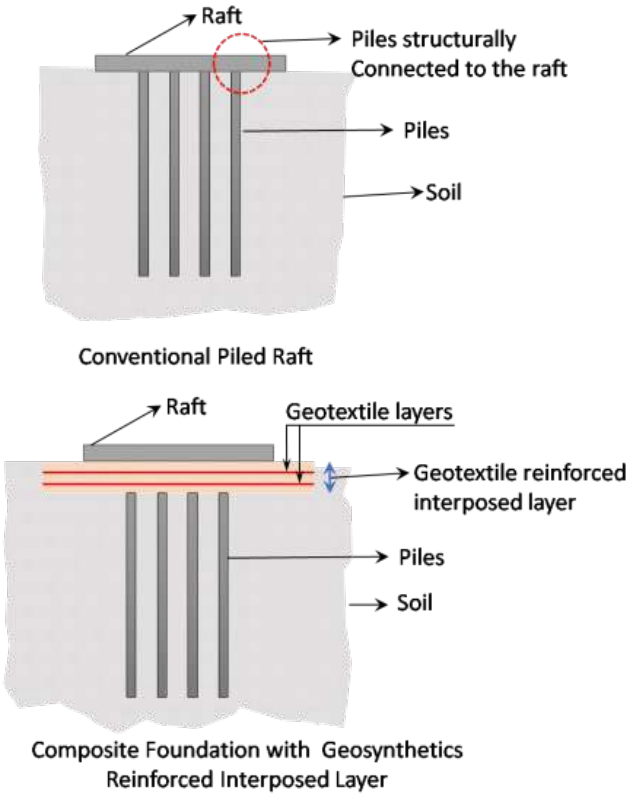
In many regions around the world, engineering structures such as earth dams, buildings, pipelines, landfills, bridges, roads and railroads have been built in areas very close to active fault segments. Strike-slip fault rupture occurs when the rock masses slip past each other parallel to the strike.

A team of researchers led by Associate Professor Behzad Fatahi and supported by PhD candidate Habib Rasouli from the School of Civil and Environmental Engineering in the UTS Faculty of Engineering and IT has recently found a ground-breaking solution to protect buildings sitting on deep foundations subjected to large ground deformations due to strike-slip fault rupture.

"The strike-slip fault rupture can significantly damage structures such as buildings and infrastructure such as bridges," Associate Professor Fatahi said. "The unacceptable performance of conventional deep foundations under strike-slip fault rupture is due to a high level of shear forces in the raft and the large deformation and bending moment in the piles supporting the structures."

Associate Professor Fatahi and his team have proposed a new composite foundation system using inexpensive polymeric materials to protect structures sitting on deep foundations.

"In this novel mitigation technique, the piles are disconnected from the building using an interposed layer of soil which is reinforced using geotextile layers," Associate Professor Fatahi said. "Geotextiles are polymeric materials made of polypropylene or polyethylene, which are manufactured in large sheets that can be easily transported to construction sites. The geotextiles embedded in the compacted sand and gravel act as isolator and reduce the impact of large ground deformations due to fault rupture."



Schematic representation of the conventional piled raft and novel composite foundation with geosynthetics reinforced interposed layer for buildings sitting on deep pile foundations

Associate Professor Fatahi and his team have developed an advanced three-dimensional computer model to evaluate the performance of commonly used connected piles and the proposed composite foundation as a novel mitigation technique. Their findings, recently published the official Journal of the International Geosynthetics Society, Geotextiles and Geomembranes, have proven that the novel mitigation technique using geotextile layers has a superior performance over the commonly used pile foundation system under strike-slip fault rupture.

"Considering an increasing world population and a need to construct more infrastructure such as bridges and buildings, this novel new foundation system can significantly improve the safety of infrastructure and substantially decrease fatality and damage due to large ground deformations," Associate Professor Fatahi said.

The team now is looking at extending the solution for protection of structures affected by ground subsidence due to mining and tunnelling activities.

(University of Technology Sydney, 16 February 2021, https://www.uts.edu.au/news/tech-design/ground-breaking-solution-quake-impact)

Geosynthetics reinforced interposed layer to protect structures on deep foundations against strike-slip fault rupture

Habib Rasouli and Behzad Fatahi

Highlights

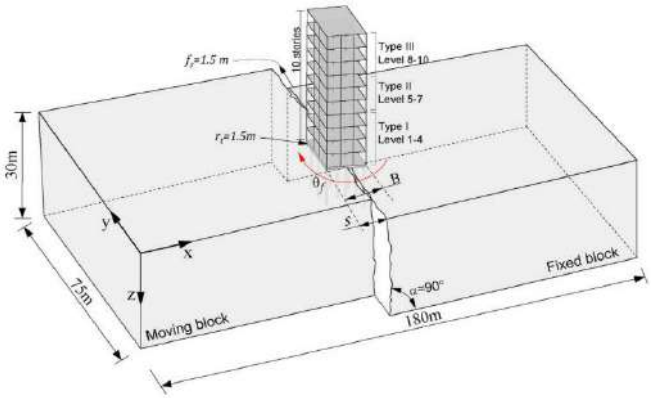
- A composite foundation, where piles were disconnected from the raft, was proposed to mitigate fault rupture effects.
- Interaction mechanism of a building sitting on the proposed composite foundation with strike-slip fault rupture was assessed.
- The proposed composite foundation exhibited a superior performance by reducing shear forces and ductility demand in piles.

Abstract

In the present study, the interaction mechanism of a 10-story moment-resisting building frame sitting on the conventional piled raft foundation with a strike-slip fault rupture with a dip angle of 90° is studied via three-dimensional finite element numerical simulation using ABAQUS. In addition, an alternative composite foundation system with geosynthetics reinforced interposed layer between piles and raft is proposed to improve the safety and performance of foundation under strike-slip fault ruptures. The interposed layer is reinforced with two high tensile strength of the geotextile layer. The inelastic behaviour of piles under large ground deformations is simulated using moment-curvature relationships of the real reinforced concrete section of piles and ductility concepts. The performance of both composite and conventional piled raft foundations are evaluated in terms of the geotechnical and structural responses of foundations including rotational and translational displacements and shear forces of the raft, as well as shear forces and ductility capacity of piles. The obtained results show the superior performance of composite foundation with geotextile reinforced interposed layer in terms of a significant reduction in shear forces in the raft and piles, as well as ductility demand in the piles.

(https://doi.org/10.1016/j.geotexmem.2020.11.011Get rights and content, https://www.sciencedirect.com/science/article/abs/pii/S0266114420301606)

New foundation design to tackle the effect of earthquake induced deformations



The numerical model for strike-slip fault simulation with a 10-story building. Credits: Rasouli and Fatahi, 2020

Scientists from the University of Technology (UTC) in Sydney, Australia, have introduced a new method to protect buildings from earthquakes.

An earthquake can be devastating for civil engineering infrastructure since dynamic loads are applied to the structures and can result in failures. Seismic design has been highly optimized over the past years with regulations introducing strict standards for buildings (especially those near earthquake-prone regions).

However, even though the induced seismic loads have been accounted for in the design, the applied deformation that a fault rupture can trigger is not generally being considered. An earthquake is triggered when a fault rupture occurs and is accompanied by certain deformations. The deformation patterns spatially affect a large region in which the ground experiences movements. Any building founded in the vicinity of an active fault can be impacted by those deformations which are most prominent in strike-slip faults. In particular, the foundation is subjected to a certain deformation that cannot always be borne due to the brittleness of the material from which it consists (usually reinforced concrete).

A solution to this problem could be avoiding areas where active faults exist but, this is not always efficient for infrastructure development. Moreover, there is a lot of uncertainty regarding the tectonic regime of a region since a lot of active faults have not been yet identified.

The researchers from UTC state that the existing regulations cannot protect structures from this phenomenon. Therefore, they present a new method that solves the problem via a deformable foundation. The findings were recently published in Geotextiles and Geomembranes.

The approach concerns deep foundations which are mainly associated with the utilization of piles. When subjected to deformation, piles will develop high shear stresses and bending moments and are prone to failures. For this reason, the team suggests that a layer of soil with reinforced geotextiles can be placed between the piles and the raft foundation to bear the imposed deformation.

The research team conducted a three-dimensional, finite element simulation to derive the behavior of a 10-story building founded both on a conventional pile foundation and on a composite foundation. The building was situated on top of a strike-slip fault which caused certain deformation to the system. The fault was simulated by dividing the model into two sections which were then moving with respect to each other at a rate of 10mm/s. Before the fault displacement, the initial conditions of the model (the soil stress state, the weight of

the foundation, the weight of the building and a live load of 5 kPa) were applied.

The results of the analyses show that the new technique proposed is beneficial for the structure which behaves better when the composite type of foundation is utilized. The authors of the study suggest that further evaluation needs to take place in the future in order to verify the beneficial impact of the proposed, composite foundation.

(Geoengineer.org, Dec, 31, 2020, https://www.geoengineer.org/news/new-foundation-design-to-tackle-earthquake-impact)

Researchers find link between earthquake timing and water cycle in Taiwan

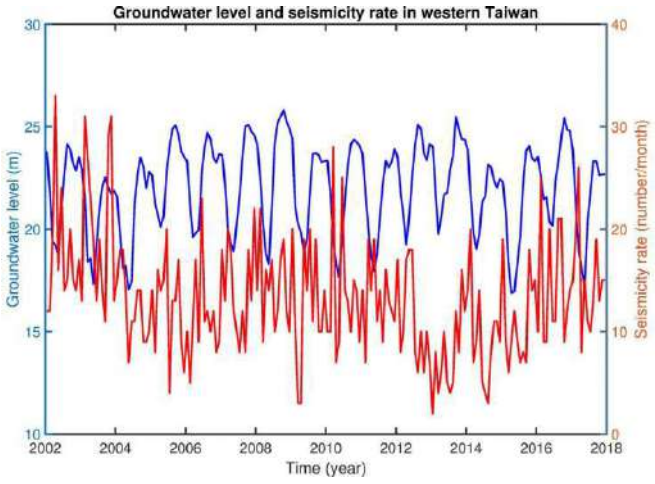
A team of researchers from Taiwan, Canada and the U.S. has found a link between the water cycle in Taiwan and the timing of earthquakes there. In their paper published in the journal *Science Advances*, the group describes their study of the water cycle in Taiwan and why it appears to be related to the timing of earthquakes.

The work began when one of the team members noticed that large earthquakes in Taiwan seemed to happen more often in the dry season. Taiwan is subjected to heavy rains and frequent typhoons each year between May and September.

In other months, the amount of rainfall is much less. Prior research has shown that because of the dramatic shifts in rainfall amounts, groundwater levels change dramatically, as well.

In this new effort, the researchers wondered if reduced groundwater levels, which leave empty cavities below ground, could be behind some of the many earthquakes experienced by the country.

To find out, they collected both earthquake and rainfall data for the country, in some cases going back several hundred years. They also added satellite data that allowed for measuring water storage on the island.



The researchers found seismic activity was indeed highest during the dry season, particularly during the driest periods of February, March and April—just before the start of monsoon season. They also found that seismic activity was most quiet from July to September—typically the wettest part of the year.

The researchers also found that the decreased water load belowground during the dry season often resulted in the land above rising, which increased the odds of earthquakes occurring. They also found that there were different factors involved in earthquakes that occurred on the east side of the island versus the west. Earthquakes that occurred on the east side of the island had a more complex pattern, and were less related to weather.

The researchers note that the annual stresses to the land beneath the island could be contributing to deeper stresses that occasionally result in ruptures of large faults, leading to some of the larger earthquakes that occasionally rock the island. Their findings could have implications for other parts of the world that experience dramatic fluctuations in rainfall each year.

More information: Ya-Ju Hsu et al. Synchronized and asynchronous modulation of seismicity by hydrological loading: A case study in Taiwan, *Science Advances* (2021). DOI: 10.1126/sciadv.abf7282

(Geology Science, April 15, 2021, https://geology-science.info/researchers-find-link-between-earthquake-timing-and-water-cycle-in-taiwan)

Synchronized and asynchronous modulation of seismicity by hydrological loading: A case study in Taiwan

Ya-Ju Hsu, Honn Kao, Roland Bürgmann, Ya-Ting Lee, Hsin-Hua Huang, Yu-Fang Hsu, Yih-Min Wu and Jiancang Zhuang

Abstract

Delineation of physical factors that contribute to earthquake triggering is a challenging issue in seismology. We analyze hydrological modulation of seismicity in Taiwan using groundwater level data and GNSS time series. In western Taiwan, the seismicity rate reaches peak levels in February to April and drops to its lowest values in July to September, exhibiting a direct correlation with annual water unloading. The elastic hydrological load cycle may be the primary driving mechanism for the observed synchronized modulation of earthquakes, as also evidenced by deep earthquakes in eastern Taiwan. However, shallow earthquakes in eastern Taiwan (<18 km) are anticorrelated with water unloading, which is not well explained by either hydrological loading, fluid transport, or pore pressure changes and suggests other time-dependent processes. The moderate correlation between stacked monthly trends of large historic earthquakes and present-day seismicity implies a modestly higher seismic hazard during the time of low annual hydrological loading.

Science Advances 14 Apr 2021: Vol. 7, no. 16, eabf7282, DOI: 10.1126/sciadv.abf7282, https://advances.sciencemag.org/content/7/16/eabf7282

Study reveals mechanism of naturally occurring 'earthquake gate'

A new study reveals the workings of an "earthquake gate" -- a naturally occurring blocker that decides which quakes are allowed to grow into M8.0 or greater.

"An earthquake gate is like someone directing traffic at a one-lane construction zone," said co-author Nicolas Barth, a geologist from the University of California, Riverside.

"Sometimes you pull up and get a green 'go' sign, other times you have a red 'stop' sign until conditions change."

Researchers found out about this gate while analyzing New Zealand's Alpine Fault, which they identified has around a 75 percent chance of generating a damaging earthquake within the next five decades.

The modeling also suggests that this earthquake has an 82 percent chance of rupturing through the gate, becoming M8.0 or greater.

The researchers, composed of scientists from the Victoria University of Wellington, GNS Science, the University of Otago, and the US Geological Survey, combined two approaches to studying quakes: evidence of past earthquakes and computer simulations.

"Big earthquakes cause serious shaking and landslides that carry debris down rivers and into lakes," said lead author Jamie Howarth, a geologist from the Victoria University of Wellington.

Researchers gathering sediment near the Alpine Fault in New Zealand.

"We can drill several meters through the lake sediments and recognize distinct patterns that indicate an earthquake shook the region nearby. By dating the sediments, we can precisely determine when the earthquake occurred."

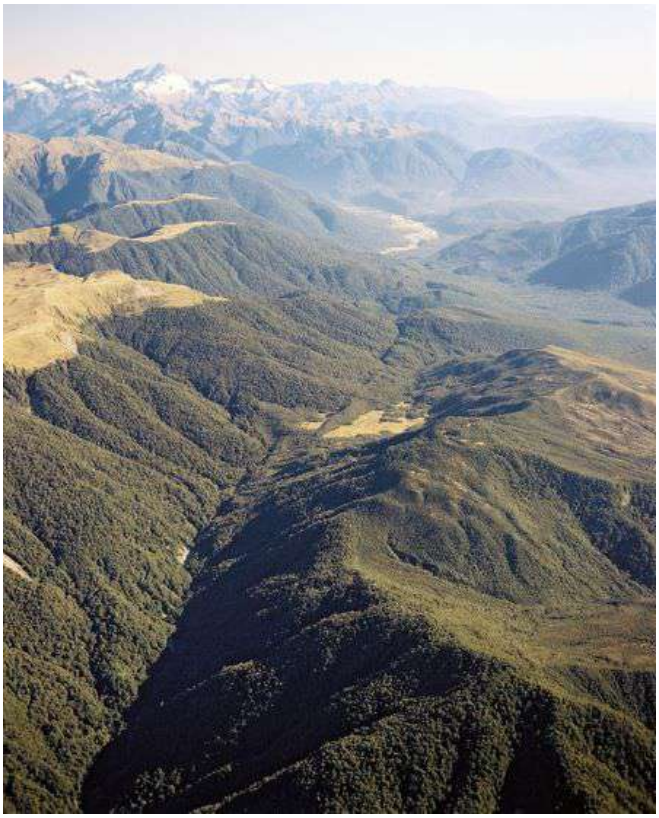
Sedimentary records collected at six areas along the Alpine Fault determined the extent of the past 20 major earthquakes over the last 4 000 years, making it one o the most detailed earthquake records in the world.

This record provided a rare opportunity for the scientists to compare their data with a 100 000-year record of computer-generated tremors.

"The simulations show that a smaller magnitude 6 to 7 earthquake at the earthquake gate can change the stress and break the streak of larger earthquakes," said Barth.

"We know the last three ruptures passed through the earthquake gate. In our best-fit model, the next earthquake will also pass 82 percent of the time."

Beyond New Zealand, earthquake gates are an important area of active research in California. Researchers are particularly targeting the Cajon Pass region near San Bernardino, where the interaction of the San Andreas and San Jacinto faults may cause earthquake gate behavior that could regulate the size of the next damaging tremor in the area.



Alpine Fault.

"We are starting to get to the point where our data and models are detailed enough that we can begin forecasting earthquake patterns. Not just how likely an earthquake is, but how big and how widespread it may be, which will help us better prepare."

Reference

"Spatiotemporal clustering of great earthquakes on a transform fault controlled by geometry" - Howarth, J. D., e al. - Nature Geoscience - https://doi.org/10.1038/s41561-021-00721-4

(Julie Celestial / THE WATCHERS, April 21, 2021, https://watchers.news/2021/04/21/study-reveals-mechanism-of-naturally-occurring-earthquake-gate)

Spatiotemporal clustering of great earthquakes on a transform fault controlled by geometry

Jamie D. Howarth, Nicolas C. Barth, Sean J. Fitzsimons, Keith Richards-Dinger, Kate J. Clark, Glenn P. Biasi, Ursula A. Cochran, Robert M. Langridge, Kelvin R. Berryman & Rupert Sutherland

Abstract

Minor changes in geometry along the length of mature strike-slip faults may act as conditional barriers to earthquake rupture, terminating some and allowing others to pass. This hypothesis remains largely untested because palaeoearthquake data that constrain spatial and temporal patterns of fault rup-

ture are generally imprecise. Here we develop palaeoearthquake event data that encompass the last 20 major-to-great earthquakes along approximately 320 km of the Alpine Fault in New Zealand with sufficient temporal resolution and spatial coverage to reveal along-strike patterns of rupture extent. The palaeoearthquake record shows that earthquake terminations tend to cluster in time near minor along-strike changes in geometry. These terminations limit the length to which rupture can grow and produce two modes of earthquake behaviour characterized by phases of major (Mw 7–8) and great (Mw > 8) earthquakes. Physics-based simulations of seismic cycles closely resemble our observations when parameterized with realistic fault geometry. Switching between the rupture modes emerges due to heterogeneous stress states that evolve over multiple seismic cycles in response to along-strike differences in geometry. These geometric complexities exert a first-order control on rupture behaviour that is not currently accounted for in fault-source models for seismic hazard.

Nature / *Nature Geoscience* (2021), https://www.nature.com/articles/s41561-021-00721-4#citeas

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

How was the Earth formed?

Just how did the Earth—our home and the place where life as we know it evolved—come to be created in the first place? In some fiery furnace atop a great mountain? On some divine forge with the hammer of the gods shaping it out of pure ether? How about from a great ocean known as Chaos, where something was created out of nothing and then filled with all living creatures?

If any of those accounts sound familiar, they are some of the ancient legends that have been handed down through the years that attempt to describe how our world came to be. And interestingly enough, some of these ancient creation stories contain an element of scientific fact to them.

When it comes to how the Earth was formed, forces that can only be described as fiery, chaotic, and indeed godlike, were involved. However, in the past few centuries, research and refinements made in what is today known as Earth Sciences have allowed scientists to assemble a more empirical and scientific understanding of how our world was formed.

Basically, scientists have ascertained that several billion years ago our Solar System was nothing but a cloud of cold dust particles swirling through empty space. This cloud of gas and dust was disturbed, perhaps by the explosion of a nearby star (a supernova), and the cloud of gas and dust started to collapse as gravity pulled everything together, forming a solar nebula—a huge spinning disk. As it spun, the disk separated into rings and the furious motion made the particles white-hot.

The center of the disk accreted to become the Sun, and the particles in the outer rings turned into large fiery balls of gas and molten-liquid that cooled and condensed to take on solid form. About 4.5 billion years ago, they began to turn into the planets that we know today as Earth, Mars, Venus, Mercury, and the outer planets.

The first era in which the Earth existed is what is known as the Hadean Eon. This name comes from the Greek word "Hades" (underworld), which refers to the condition of the planet at the time. This consisted of the Earth's surface being under a continuous bombardment by meteorites and intense volcanism, which is believed to have been severe due to the large heat flow and geothermal gradient dated to this era.

Outgassing and volcanic activity produced the primordial atmosphere, and evidence exists that liquid water existed at this time, despite the conditions on the surface. Condensing water vapor, augmented by ice delivered by comets, accumulated in the atmosphere and cooled the molten exterior of the planet to form a solid crust and produced the oceans.

It was also during this eon – roughly 4.48 billion years ago (or 70–110 million years after the start of the Solar System) – that the Earth's only satellite, the Moon, was formed. The most common theory, known as the "giant impact hypothesis" proposes that the Moon originated after a body the size of Mars (sometimes named Theia) struck the proto-Earth a glancing blow.

The collision was enough to vaporize some of the Earth's outer layers and melt both bodies, and a portion of the mantle material was ejected into orbit around the Earth. The ejecta in orbit around the Earth condensed, and under the influence of its own gravity, became a more spherical body: the Moon.

The Hadean Eon ended roughly 3.8 billion years ago with the onset of the Archean age. Much like the Hadean, this eon takes its name from an ancient Greek word, which in this case means "beginning" or "origin." This refers to the fact that it was during this period that the Earth had cooled significantly and life forms began to evolve.

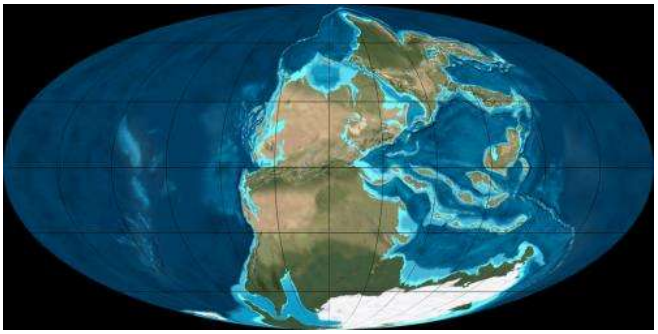
Most life forms today could not have survived in the Archean atmosphere, which lacked oxygen and an ozone layer. Nevertheless, it is widely understood that it was during this time that most primordial life began to take form, though some scientists argue that many lifeforms may have occurred even sooner during the late Hadean.

At the beginning of this Eon, the mantle was much hotter than it is today, possibly as high as 1600 °C (2900 °F). As a result, the planet was much more geologically active, processes like convection and plate tectonics occurred much faster, and subduction zones were more common. Nevertheless, the presence of sedimentary rock date to this period indicates an abundance of rivers and oceans.

The first larger pieces of continental crust are also dated to the late Hadean/early Achean Eons. What is left of these first small continents are called cratons, and these pieces of crust form the cores around which today's continents grew. As the surface continually reshaped itself over the course of the ensuing eons, continents formed and broke up.

The continents migrated across the surface, occasionally combining to form a supercontinent. Roughly 750 million years ago, the earliest-known supercontinent called Rodinia

began to break apart, then recombined 600 – 540 million years ago to form Pannotia, then finally Pangaea. This latest supercontinent broke apart 180 million years ago, eventually settling on the configuration that we know today.



Since that time, a mere blip on the geological time scale, all the events that we consider to be "recent history" took place. The dinosaurs ruled and then died, mammals achieved ascendancy, hominids began to slowly evolve into the species we know as homo sapiens, and civilization emerged. And it all began with a lot of dust, fire, and some serious impacts. From this, the Sun, Moon, Earth, and life as we know it were all created.

Provided by **Universe Today**.

(Geology Science, April 7, 2021, https://geology-science.info/how-was-the-earth-formed)

How Old is the Earth?
https://www.youtube.com/watch?v=hKGMqCqWpNc&t=24s

Formation of the moon brought water to Earth

The Earth is unique in our solar system: It is the only terrestrial planet with a large amount of water and a relatively large moon, which stabilizes the Earth's axis.

Both were essential for Earth to develop life. Planetologists at the University of Münster (Germany) have now been able to show, for the first time, that water came to Earth with the formation of the Moon some 4.4 billion years ago. The Moon was formed when Earth was hit by a body about the size of Mars, also called Theia.

Until now, scientists had assumed that Theia originated in the inner solar system near the Earth. However, researchers from Münster can now show that Theia comes from the outer solar system, and it delivered large quantities of water to Earth. The results are published in the current issue of *Nature Astronomy*.

From the outer into the inner solar system

The Earth formed in the 'dry' inner solar system, and so it is somewhat surprising that there is water on Earth. To understand why this the case, we have to go back in time when the solar system was formed about 4.5 billion years ago.

From earlier studies, we know that the solar system became structured such that the 'dry' materials were separated from the 'wet' materials: the so-called 'carbonaceous' meteorites, which are relatively rich in water, come from the outer solar system, whereas the drier 'non-carbonaceous' meteorites come from the inner solar system.

While previous studies have shown that carbonaceous materials were likely responsible for delivering the water to Earth, it was unknown when and how this carbonaceous material—and thus the water—came to Earth.

"We have used molybdenum isotopes to answer this question. The molybdenum isotopes allow us to clearly distinguish carbonaceous and non-carbonaceous material, and as such represent a 'genetic fingerprint' of material from the outer and inner solar system," explains Dr. Gerrit Budde of the Institute of Planetology in Münster and lead author of the study.

The measurements made by the researchers from Münster show that the molybdenum isotopic composition of the Earth lies between those of the carbonaceous and non-carbonaceous meteorites, demonstrating that some of Earth's molybdenum originated in the outer solar system. In this context, the chemical properties of molybdenum play a key role because, as it is an iron-loving element, most of the Earth's molybdenum is located in the core.

"The molybdenum which is accessible today in the Earth's mantle, therefore, originates from the late stages of Earth's formation, while the molybdenum from earlier phases is entirely in the core," explains Dr. Christoph Burkhardt, second author of the study. The scientists' results therefore show, for the first time, that carbonaceous material from the outer solar system arrived on Earth late.

But the scientists are going one step further. They show that most of the molybdenum in Earth's mantle was supplied by the protoplanet Theia, whose collision with Earth 4.4 billion years ago led to the formation of the Moon.

However, since a large part of the molybdenum in Earth's mantle originates from the outer solar system, this means that Theia itself also originated from the outer solar system. According to the scientists, the collision provided sufficient carbonaceous material to account for the entire amount of water on Earth.

"Our approach is unique because, for the first time, it allows us to associate the origin of water on Earth with the formation of the Moon. To put it simply, without the Moon there probably would be no life on Earth," says Thorsten Kleine, Professor of Planetology at the University of Münster.

More information: Gerrit Budde et al, Molybdenum isotopic evidence for the late accretion of outer Solar System material to Earth, *Nature Astronomy* (2019). DOI: 10.1038/s41550-019-0779-y

Provided by University of Münster.

(Geology Science, April 4, 2021, https://geology-science.info/formation-of-the-moon-brought-water-to-earth/)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

G.R.I.T.
GUTS, RESILIENCE, INITIATIVE, TENACITY

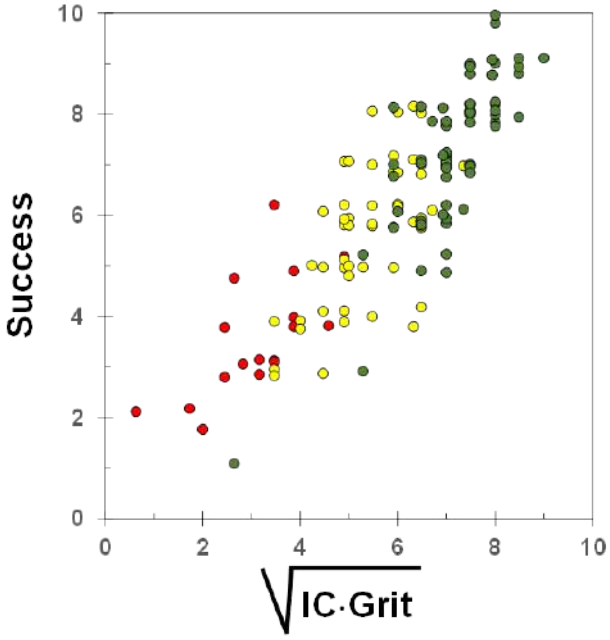
Carlos Santamarina

You may have heard about GRIT (see https://www.ted.com/talks/angela_lee_duckworth_grit_the_power_of_passion_and_perseverance?language=en)

Bottom line: success (S) is not just defined by intellectual capacity (IC): mental fortitude, perseverance of effort, resilience (let's call it Grit) play a critical role as well.

Invited to give a talk on the topic, I decided to collect some of our own data. The figure bellow is a sneak peek… Clearly, there are other factors towards success, such as focused dedication. Still, the correlation is surprising, isn't it?! In fact, it supports a predictive model: S= sqrt(IC.Grit).

Other important dimensions to life -besides success- gain relevance in retrospect. So, I have also explored individuals' "satisfaction/harmony" (more difficult to assess!). As you may guess, there is hardly any correlation between "satisfaction" and intellectual capacity, dedication, or grit…



ΝΕΕΣ ΕΚΔΟΣΕΙΣ ΣΤΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΠΙΣΤΗΜΕΣ

Piling 2020: Proceedings of the Piling 2020 Conference

British Geotechnical Association

Piling 2020 contains the proceedings of the Piling 2020 conference, organised by the British Geotechnical Association (BGA) and supported by the Federation of Piling Specialists (FPS). It brings together the knowledge and experience of industry and academia through detailed research and case histories that provide a definitive and up to date perspective on geotechnical aspects of offshore and onshore piling projects. The papers reflect the themes of the conference which include

- design of piles and embedded retaining walls
- research on piling and piled systems
- materials
- temporary works
- case histories
- methods of construction
- instrumentation and monitoring
- sustainability
- digital issues.

This fascinating collection of papers is of interest to all who work within the broad field of geotechnical engineering, including geotechnical engineers, engineering geologists and piling professionals as well as those in academia.

(ICE Publishing, 10 March 2021)

Earthquake Design Practice for Buildings, Fourth edition

Damian Grant and Edmund Booth

Earthquake Design Practice for Buildings covers the main principles and design rules that are used to design buildings to resist the ef-fect of earthquakes. It offers comprehensive, practical and easy to read advice on the technical issues that have to be considered in the seismic design of buildings. This indispen-sable guide outlines the principles of structural dynamics used to establish how a building and its foundations respond to strong ground shaking. Extensive advice is provided on the choice and design of structural forms and materials which produce practical, affordable and attractive buildings resilient to earthquakes.

Now in its fourth edition and written by two experienced seismic engineers, this book has been updated to take into account the many developments in seismic design practice in recent years, including updates to international seismic design standards, along with new editions of US design standards, upcoming changes to Eurocode 8, and a comparison with Indian and Chinese code requirements

- a new chapter on seismic performance objectives for new and existing structures, and the latest developments in performance-based earthquake engineering (PBEE)
- expanded coverage on the design of masonry and timber structures
- design of specific seismic-protective technologies, such as base isolation and supplemental damping, and the role of 'non-structural' building components in delivering resilient, damage-resistant seismic design
- a revised introduction on the wider technical and socio-economic factors affecting earthquake resilience.

Containing information about the updated international seismic standards, *Earthquake Design Practice for Buildings* is directed at practising engineers and advanced-level students seeking a broad survey of the latest developments in seismic engineering. It also appeals to those who have a sound general knowledge of structural design but who may be unfamiliar with the problems of providing earthquake resistance.

Book Reviews

This book succeeds in achieving the difficult balance of being relatively straightforward to follow for an engineer with limited background in the subject, whilst being very informative and engaging for more experienced readers who want to update their knowledge and skills in seismic design. Although the main focus of the book is on the behaviour, design and assessment of buildings, it also raises awareness of the wider economic and societal considerations related to earthquake resilience. The book meets the needs of a wide international audience, as there is emphasis on explaining the underlying fundamental concepts without reliance on a specific code of practice. Nonetheless, the basis and procedures of a number of international design standards are presented, discussed and compared, including those from the European, North American, Indian and Chinese seismic codes.

Ahmed Elghazouli FREng, Professor of Structural Engineering, Imperial College London, UK

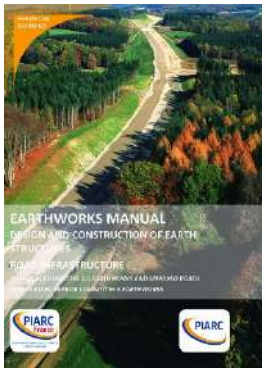
Special features of this edition which will make it particularly valuable to engineering designers are:

- *its timely account of the Eurocodes, now finally becoming published documents and soon to become mandatory in some areas, with which Edmund Booth has been closely involved*
- *the excellent chapter on conceptual design, setting out some fundamentals which should be thought about while a building's form and siting are still being developed, and which architects as well as engineers will find illuminating*
- *a valuable new chapter on the assessment and strengthening of existing buildings, an activity whose importance is already growing in many countries, as we look for ways to protect our urban centres from future earthquake disasters*

- *an excellent state of the art on seismic isolation, rightly identified by the authors as 'an idea whose time has come.*

Professor Robin Spence, President, European Association for Earthquake Engineering, Cambridge, UK

(ICE Publishing, 06 November 2020)



Earthworks Manual

Design and Construction of Earth Structures

Road Infrastructure

Technical Committee 4.4 Earthworks and Unpaved Roads

French PIARC Piror Committee 8 Earthworks

The Earthworks Manual project was launched in 2012 by the Executive Committee of the PIARC Strategic Plan, which entrusted its preparation to Technical Committee 4.4 "Earthworks and unpaved roads".

The Earthworks Manual is an important technical document for the profession and stakeholders in the field of activity. It is eagerly awaited by the experts from many countries who have contributed to its content.

The Manual is organised in two parts:

- Part 1: General considerations
- Part 2: Specific technical developments

The genesis, which can be downloaded on this page, allows an appreciation of the importance of the contributions of PIARC members within the Technical Committee 4.4, the contribution of European Standards work on the Earthworks Theme in the same period, as well as the development of complementary technical themes proposed in the work of the PIARC France "Earthworks" Committee.

The International Seminars organised by PIARC have also provided papers and presentations relevant to the contents of the Manual. These contributions are mentionned in the Preamble, gathering the technical references, terminology and glossary elements used in the development of the different parts of the Manual.

(PIARC, 2021, https://www.piarc.org/en/order-library?publication=35192&solo)

Contractual framework checklist for subsurface construction contracts

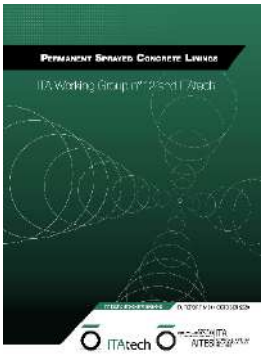
ITA WG3

This guideline was produced by ITA WG3. The 2nd edition of the Contractual Framework Checklist builds upon the 1st edition by identifying and clarifying key contractual practice subject areas that ITA believes are fundamental for the success of subsurface construction pro-jects independently of the form of contract and risk appor-tionment used. This 2nd edition also endorses third party documents that ITA considers to have special subject matter or geographic significance and will further assist formulation of contractual practices for improved project performance.

ITA believes most existing standard forms of construction guidelines and contracts could deal better with the variabilities inherent in subsurface environments, and the impact of those variabilities when an Employer seeks to have an underground facility constructed in this variable environment. Application of this Contractual Framework Checklist will help all parties achieve the ultimate objectives of on-time, on-budget and fitness for purpose delivery of the subsurface (below the surface of the earth, be it water or land) infrastructure.

Download document

(ITA, 13 April 2021)



Permanent sprayed concrete linings report

ITAtech Activity group Lining & WG 12

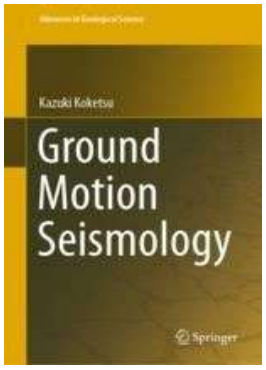
Among the series of guidelines published this year, find the report N° 24 on Permanent Spayed Concrete Linings produced by ITAtech Activity group Lining & WG 12.

The main objective of this guideline is to give infrastructure owners and their advisors the confidence to incorporate permanent sprayed concrete linings (PSCL) into their underground space design. In line with the objectives of the ITA Statutes this document aims to encourage the use of tunnels and underground space for the benefit of the public, the environment and sustainable development and to promote advances in tunnelling through the provision of information. This guideline will share state-of-the-art expertise on PSCL to encourage wider acceptance of this tried-and-tested solution. PSCL can be used for primary linings, secondary linings or both. Using PSCLs can lead to lower capital costs, operational costs and carbon footprints when compared to tradetional lining solutions. Wider adoption of PSCLs will have a positive impact on the sustainability of underground spaces and increase their viability and potential uses.

This document is not intended to be a comprehensive design guide or construction specification. Instead it aims to inspire and inform so that more projects can take advantage of this technology. It focuses on wet sprayed concrete and machine application since PSCL is almost always applied in this way. This document is specific to PSCL and does not discuss routine construction practices. It does not replace the need for expert advice during planning, design or construction, but should give project teams a resource for understanding the key risks and issues and how to manage them. The approaches proposed here can be adapted to a specific project to suit the parties involved and the details of each scheme.

Download document

(ITA, 17 December 2020)



Ground Motion Seismology

Kazuki Koketsu

This book explains the physics behind seismic ground motions and seismic waves to graduate and upper undergraduate students as well as to professionals. Both seismic ground motions and seismic waves are terms for "shaking" due to earthquakes, but it is common that shaking in the near-field of an earthquake source is called seismic ground motion and in the far-field is called seismic waves. Seismic ground motion is often described by the tensor formula based on the representation theorem, but in this book explicit formulation is emphasized beginning with Augustus Edward Hough Love (1863 – 1940). The book also explains in depth the equations and methods used for analysis and computation of shaking close to an earthquake source. In addition, it provides in detail information and knowledge related to teleseismic body waves, which are frequently used in the analysis of the source of an earthquake.

(Spinger, 2021)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

ITA@NEWS

https://about.ita-aites.org/news

Κυκλοφόρησε το Τεύχος #73 (Απριλίου 20201) των ITA News με τα παρακάτω περιεχόμενα:

MESSAGE FROM JINXIU (JENNY) YAN, ITA PRESIDENT

Dear ITA colleagues,

Thanks to the digital tools available nowadays, ITA can continue its work in a digital way even during this difficult time. Currently, ITA ExCo has more frequent meetings then ever before, increasing from 5 meetings in a normal year in the past to monthly meetings now. Moreover, we have organized more digital training courses this year, that is, the ITA-CET monthly lunchtime online lecture, which received positive feedback.

With the recent surge in digital activities, it has become a common practice to add an additional digital event to physical events to reach more participants. Last week, I attended in person the 2021 Shanghai International Tunnelling Symposium, which was held on April 18th and 19th. The event, taking advantage of digital technology, not only gathered around 500 in person participants but also attracted around 2 million real time online visits!

As you know, one of our priorities is to communicate with international banks to share knowledge and increase the contributions of tunnelling in implementing Sustainable Development Goals. Since 2019, we have been communicating with AIIB (Asian Infrastructure Investment Bank). Both sides have known more about each other and realized there were various opportunities for cooperation. This year, on March 23rd, we organized an initial ITA-AIIB meeting in AIIB headquarters in digital and physical ways. Both sides have agreed to work together on joint workshop, training courses and capability building related to tunnelling and underground space.

Last but not at least, the 47th General Assembly is going to be held digitally on June 30th. I am looking forward to meeting you all soon!

Yours sincerly

Jinxiu (Jenny) Yan
President of ITA 2019-2022

- Initial meeting between ITA and AIIB Read more
- World Tunnel Congress 2023 in Athens Read more
- WTC 2022: Call for abstracts Read more
- ITA 2021 publication: Contractual framework checklist for subsurface construction contracts Read more
- 47th ITA General Assembly
- RETC - Rapid Excavation & Tunnelling Conference Read more
- Online training session: Calculation methods for tunnel design Read more
- ITA 2020 publication: Permanent sprayed concrete linings report Read more
- ITA awards 2021 entries platform to be opened soon Read more
- ITA-CET online lunchtime lecture is pursuing its path! Read more
- Webinar on "Planning for sustainable underground space" Read more
- Australasian Tunnelling Conference 2020+1 Read more

International Geosynthetics Society

Κυκλοφόρησε το IGS Newsletter της International Geosynthetics Society με τα παρακάτω περιεχόμενα:

IGS NEWSLETTER – April 2021

Helping the world understand the appropriate value and use of geosynthetics

httpwww.geosyntheticssociety.org/newsletters

- Did You Know: Geosynthetics and the SDGs READ MORE
- Introducing IGS Executive Director John Kraus READ MORE
- Special issue on "Durability of Geosynthetics" READ MORE
- IGS Foundation Scholars Share Their Experience READ MORE
- Fresh Content In IGS Digital Library READ MORE
- What's Happening In Your Chapter in 2021? READ MORE
- 10 Questions With… Dawie Marx READ MORE
- IGS Chapter Focus: Iran READ MORE
- Educate The Educators In 2021 READ MORE
- Exciting Year Ahead For Young Members READ MORE
- Iran Chapter: Post-Webinar Summary Report READ MORE
- Upcoming Webinars
  Soft Site Impoundment Closures Webinar REGISTRATION INFORMATION
  Mining Webinar (in Spanish) REGISTRATION INFORMATION
  Geosynthetic Longevity Webinar ZOOM LINK
  Thermal Welding Webinar REGISTRATION INFORMATION
- Calendar of Events

www.sciencedirect.com/journal/geotextiles-and-geomembranes/vol/49/issue/2

Κυκλοφόρησε το Τεύχος 2 του Τόμου 49 (Απριλίου 2020) του Geotextiles and Geomembrabes της International Geosynthetics Society ως Special issue on "Application of geosynthetics in geoenvironmental engineering", edited by Haijian Xie, Liang-tong Zhan, με τα παρακάτω περιεχόμενα:

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Performance of multicomponent GCLs in high salinity impoundment applications, R. Kerry Rowe, A.Y. AbdelRazek, Pages 358-368

A DEM analysis of geomembrane-lined landfill subject to vertical loading, Juan Hou, Hao Li, Lei Liu, Shihan Wang, ... Shifen Bao, Pages 369-375

Analytical solutions for contaminant diffusion in four-layer sediment-cap system for subaqueous in-situ capping, Jinwei Qiu, Hefu Pu, Xunlong Chen, Junjie Zheng, Pages 376-387

Dynamic shear behaviors of textured geomembrane/nonwoven geotextile interface under cyclic loading, Ji-Yun Chang, Shi-Jin Feng, Pages 388-398

Physical and numerical modelling of strip footing on geogrid reinforced transparent sand, Jianfeng Chen, Xiaopeng Guo, Rui Sun, Sathiyamoorthy Rajesh, ... Jianfeng Xue, Pages 399-412

Experimental study on the permeability and self-healing capacity of geosynthetic clay liners in heavy metal solutions, Chuang Yu, Yu Yang, Ze-xiang Wu, Ji-fang Jiang, ... Yong-feng Deng, Pages 413-419

Hydraulic conductivity of bentonite-polymer composite geosynthetic clay liners permeated with bauxite liquor, Qin Li, Jiannan Chen, Craig H. Benson, Daoping Peng, Pages 420-429

Field behaviors of a geogrid reinforced MSW slope in a high-food-waste-content MSW landfill: A case study, Han Ke, Pengcheng Ma, Jiwu Lan, Yunmin Chen, Haijie He, Pages 430-441

Experimental investigation on methane advection and diffusion in geosynthetic clay liners, Qiao Wang, Haijian Xie, Jiawei Wu, Liangtong Zhan, Zhanhong Qiu, Pages 442-451

Combined vacuum and surcharge preloading method to improve lianyungang soft marine clay for embankment widening project: A case, Jun Wu, Youjin Xuan, Yongfeng Deng, Xingqi Li, ... Annan Zhou, Pages 452-465

Performance issues of barrier systems for landfills: A review, Nathalie Touze-Foltz, Haijian Xie, Guillaume Stoltz, Pages 475-488

Analytical model for coupled consolidation and diffusion of organic contaminant transport in triple landfill liners, Huaxiang Yan, Jiawei Wu, Hywel R. Thomas, Hao Ding, ... Haijian Xie, Pages 489-499

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