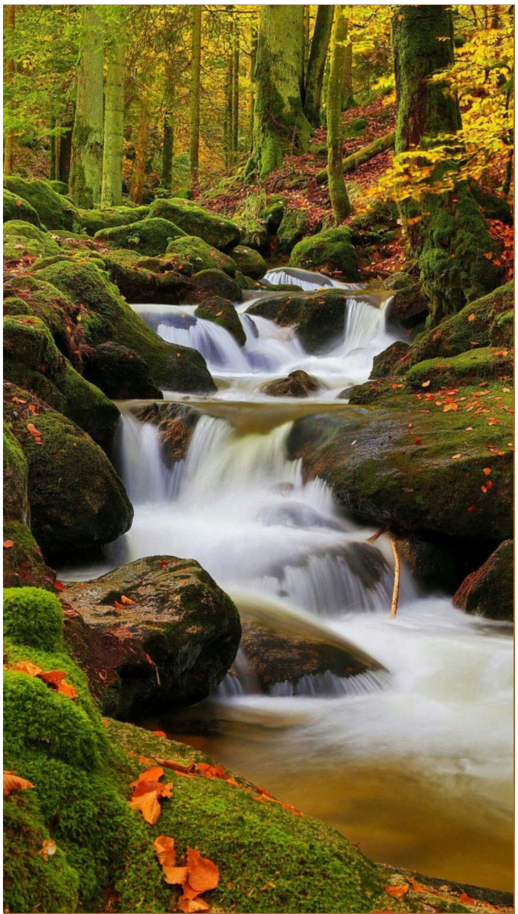


ΕΛΛΗΝΙΚΗ
ΕΠΙΣΤΗΜΟΝΙΚΗ
ΕΤΑΙΡΕΙΑ
ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ
& ΓΕΩΤΕΧΝΙΚΗΣ
ΜΗΧΑΝΙΚΗΣ

Τα Νέα της Ε Ε Ε Ε Γ Μ

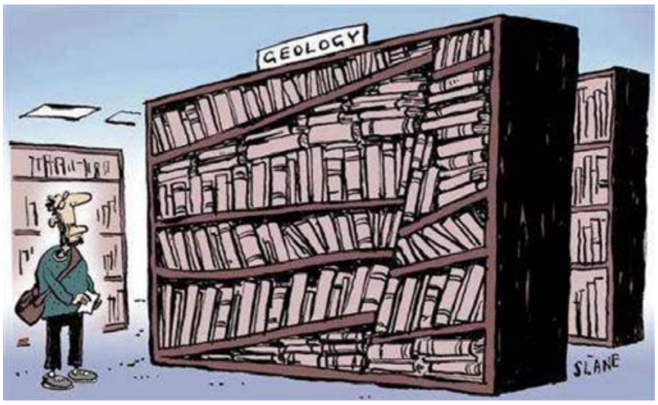
102

Αρ. 102 – ΜΑΙΟΣ 2017

SIMSG ISSMGE

ISRM

Π Ε Ρ Ι Ε Χ Ο Μ Ε Ν Α



ΑΡΘΡΑ

Παρουσίαση άρθρων, στην συγγραφή των οποίων μετείχαν Έλληνες, στο XVI European Conference on Soil Mechanics and Geotechnical Engineering, Edinburgh, 13-17 September 2015 (κατ' αλφαβητική σειρά, στα ελληνικά, του ονόματος του πρώτου συγγραφέα).

The use of fibre optic instrumentation to monitor the O-Cell load test on a single working pile in London

L'utilisation de la fibre optique instrumentation pour surveiller le test de charge O-Cell sur un tas de travail unique à Londres

Y. Ouyang, K. Broadbent, A. Bell, L. Pelecanos and K. Soga

ABSTRACT A large diameter pile was constructed in London to support 18 MN of structural load. The pile was designed to rely heavily on the base bearing capacity which is founded in the underlying Thanet Sand material. Base grouting was also specified and the pile was designed to be tested by the Osterberg load cell (O-Cell) up to the working capacity. The Osterberg load cell will remain within the pile after the testing, and such an approach requires additional consideration compared to the more usual use of an O-Cell within a sacrificial pile. The pile was instrumented by both conventional Vibrating Wire Strain Gauge(VWSG) and novel Optical Fibre Sensor(OFS) during the pile base grouting and the O-Cell pile test. The distributed temperature measurement during the concrete hydration period was also captured. This paper discusses the results obtained from both VWSG and OFS during the O-Cell test, and provides information about the pile bearing capacity and recommendations with regard to the use of O-Cell within working piles.

1 INTRODUCTION

Fibre optic instrumentation has been proven as an accurate and efficient monitoring tool for use in the UK construction industry in recent years. One type, the Brillouin scattering based fibre optic technology allows for continuous (in space) measurement of strain and temperature along one conventional telecommunicating fibre optic cable over a long distance (>30 km) (Bennett et al. 2006; A. Klar et al. 2006; Thevenaz, Nikles, & Fellay 1998; Thévenaz 2006). It offers more opportunity for engineers to acquire additional information about the behaviour of the infrastructure compared with conventional point based instrumentation. Therefore the distributed sensing has made this technology economically attractive to the construction industry.

A few early applications of such technology were reported mostly in detecting long distant pipeline leakage within the offshore industry. In recent years this technology has gradually gained popularity in infrastructure sensing with improved performance in its spatial resolution and accuracy (Mohamad et al. 2007; Ohno et al. 2001). Most construction industry applications have less demand for long distance sensing (typically a maximum of 5 km), but do however require higher spatial resolution for detecting micro deformation. The available commercial analysers offer two typical ranges of spatial resolution of 1 m or 0.5 m depending on the backscattering sensing technology. Brillouin Optical Time Domain Reflectrometry – BOTDR is based on the spontaneous Brillouin back-scattered signal and the spatial resolution is limited to 1 m with one-end access, whereas the BOTDA (named BOTDA, A for analysis) improves the spatial resolution to 0.5 m but requires access to both ends of the fibre optic cable. Therefore the selection of analyser is also restricted by the risk to the integrity of fibre optic cable installed within the infrastructure. The embedded fibre optic cable with breakages only permits the use of BOTDR, which poses challenges for the safe installation of fibre optic cables on site.

This paper presents a recent application of fibre optic sensors to monitor an Osterberg load cell (O-Cell) test on a single working test pile in London. The field measurement from two sets of independent instrumentation system (fibre optic and conventional strain gauges) has been carefully studied and compared with the original geotechnical design to evaluate and understand the bearing capacity of the pile.

2 SITE DISCRIPTION AND FIELD INSTALLATION

2.1 Site description

The site is situated in the east of London, approximately 700 m north of the River Thames. The main works comprised of 26No. Bearing piles divided between 15No permanently sleeved piles and 11No. unsleeved piles, with average safe working load capacities of 17.4 MN. One of the higher capacity unsleeved piles was selected to install a load cell under the working pile test scheme in order to understand bearing capacity and settlement as well as verify the assumed design parameters of the soil.

The test pile was constructed primarily in London Clay overlaying the Upnor formation with the toe of the pile founding in the Thanet Sands. Thanet sand is a fine and almost single size marine silty sand, which has a high relative density indicated by the Standard Penetration Test (SPT) with 'N' value in excess of 100 for 300 mm penetration.

The pile, with final depth of 31.6 m and a diameter of 2.1 m, was constructed using bentonite support fluid from a depth of 23m on 16th May 2013. It was also installed with four base grouting circuits and two extensometer tubes within the reinforcement cages to allow 3 phases of grouting and sonic logging. All tubes and reinforcement bars were scored and cut respectively at the O Cell level to allow the cage to separate. The pile was sonic logged and base grouting commenced one week after the pile construction, the last phase was completed on 30th May 2013. Upon completion all tubes were grouted.

The reinforcement cage was installed with two 25MN Osterberg Load Cells between two thick plates with allocated cut outs to allow effective concrete flow and tremmie pipe insertion to carry out a 36MN load test. The O-Cell test was conducted on 26th June 2013 and the performance of the pile was monitored by two independent sets of strain sensing system: Vibrating Wire Strain Gauge (VWSG), and Optical Fibre Sensor (OFS), as shown in Figure 1, to investigate the relationship between effective vertical stress and the bearing capacity.

In addition to the strain systems, paired upper compression tell tales were installed within the reinforcement cage to monitor uplift as well as paired toe displacement tell tales to monitor downward settlement. Linear Vibrating Wire Displacement Transducers (LVWDT's) were installed, positioned between upper and lower plates, to monitor the cell expansion.

2.2 Field installation and testing

There were two sister bar VWSGs installed at eight levels (one below the Load Cell and seven above), whilst the OFS cables were attached to the reinforcement cage along the pile shaft. The relevant position of each instrument, the cage configuration and field installation shown in Figure 1 is inline with efficient field installation procedures, which can be carried out by the engineer on site with minimum risk to health and safety and without hindrance to the pile installation process. OFS cable and the VWSG were connected to the data logger immediately after the installation.

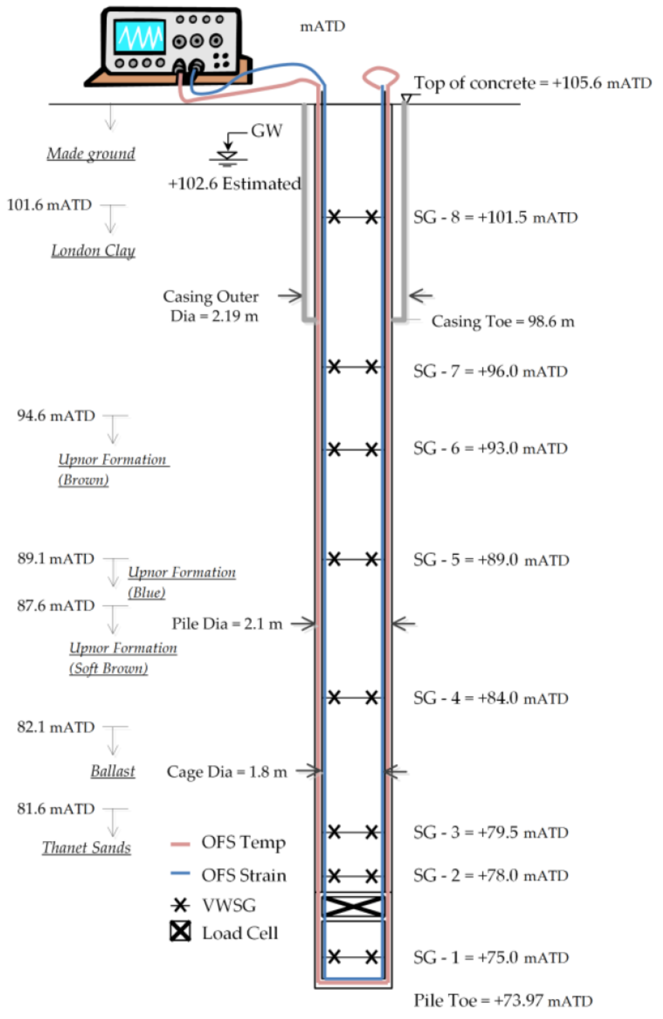


Figure 1. Ground information and instrumentation details

3 FIELD TESTING AND DATA ANALYSIS

In order to deal with potential negative skin friction and to avoid loading on adjacent tunnels, permanent liners were recommended. The geotechnical design allows a reduction on the pile shaft resistance for the un-sleeved pile, whereas the shaft resistance for the length of the liner will be ignored for the sleeved pile. Therefore the pile capacity was heavily reliant on the base bearing founding in the Thanet Sand layer. The toe of the Thanet sand layer was approximated at 71.0 mATD in the design parameters but found at 72.2 mATD on site. It was important to keep the piles founding within the layer to gain the designed end bearing capacity, although it could potentially lead to a reduction to the factor of safety for the shaft. Base grouting was used to reduce the settlements required to activate the end bearing resistance. The use of base grouting is taken into consideration only under exceptional circumstances, which arises when a specific combination of structural and geotechnical conditions are present, forcing a high reliance on the end bearing capacity of the piles at the working condition (Troughton and Stocker 1996).

The instrumented pile was base grouted one week after the installation (one month prior to the load test), and the performance of the pile under grouting was captured by the OFS sensors at different locations around the circumference of the pile, however, this paper will only focus on the results from the O-cell test and evaluating the performance of the pile with the geotechnical design.

The pile is designed to take the Specified Working Load (SWL) of ~20 MN and Design Verification Load (DVL) of ~22 MN. The O-cell included two loading cycles and the holding time for each loading increment is shown in Table 1. The loading schedule specified in the ICE SPERW (ICE 2007) was adjusted to accommodate the working pile test procedure for the use of a bi-directional O-Cell through one-direction jack load of 18MN in each direction to give the maximum test load of 36MN. Each phase was required to be held for a minimum duration until the creep rate in both upward and downward directions is less than 0.1 mm per 20 mins or 1% of the total displacement per hour but for no longer than 3 hours maximum at intermediate loads.

Table 1. O-Cell loading schedule during the pile test.

1st Loading Cycle		2nd Loading Cycle	
Time (26/06/2013)	Load [MN]	Time (27/06/2013)	Load [MN]
13:24	0	01:04	6
14:01	2	01:38	12
14:36	4	02:14	14
15:10	6	02:49	16
15:43	8	08:55	18
16:19	10	09:40	12
16:50	12	09:54	6
23:06	8	10:08	0
23:22	4		
23:39	0		

The expansion of the O-Cell has displaced the majority of movement (75%) at the pile toe compared with the uplift of the pile (25%) in the first loading cycle in Figure 2. Downward movement indicates displacement of the bottom plate of the O-Cell, and the relative movement between the downward movement of the pile toe. The movement at the pile toe indicates the compression of the pile at the pile lower section. The displacement of the upper pile section with 10 MN load was roughly 0.5 mm in the first loading cycle, and 0.9 mm with 18 MN of load in the second loading cycle respectively. The relative movement between the top of the pile and the upper plate of the O-Cell shows a similar magnitude to the lower pile section in both loading cycles, however, the measurement at the top of the pile was compensated for by the reference beam which fluctuated slightly compared to the movement of the O-Cell plate.

The determination of load distribution from the strain measurement is often subject to the assumption that the load is linearly proportional to the measured strains and the Young's modulus. However, only the Young's modulus of steel is constant throughout the pile, and the modulus of concrete can potentially vary within a wide range as mentioned by (Bourne-Webb et al. 2009). In order to arrive at a suitable stiffness for the pile shaft, the method proposed by (Fellenius 2001) was implemented using data from both the initial and the second loading test, from which an effective tangent stiffness was derived in Figure 3. The data suggests some reduction with the increasing magnitude of strain below 30 με, the effective modulus was selected based on the strain range (35με to 50με) which is likely to mobilise during the pile loading test as indicated in Figure 4. This selected stiffness will be adopted in back-calculating the load profile along the pile shaft during each load test cycle.

The pile-head response from each loading phase with different load increments have suggested that the load imposed by the O-Cell has been maintained relatively well throughout the testing period in Figure 2. The strain and load profile along the pile shaft from the two loading cycles has been selected to evaluate the pile performance against the pile design.

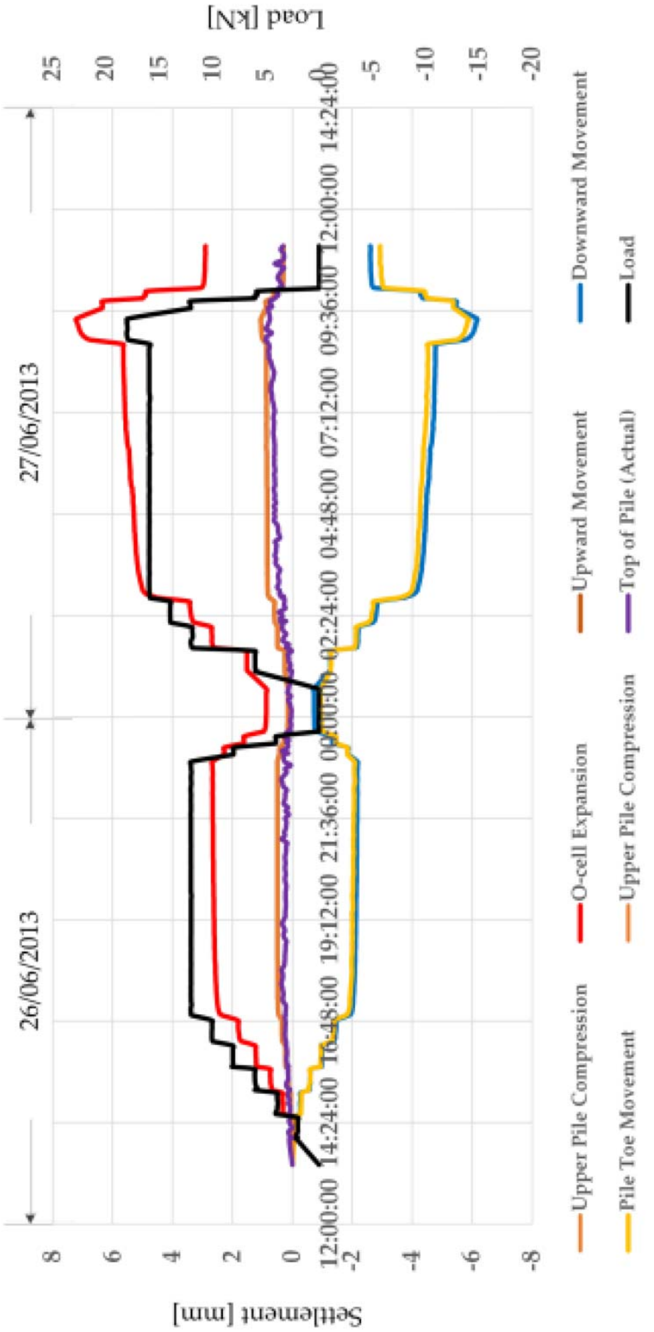


Figure 2. Applied load from O-Cell and the settlement measurement at different positions along the pile.

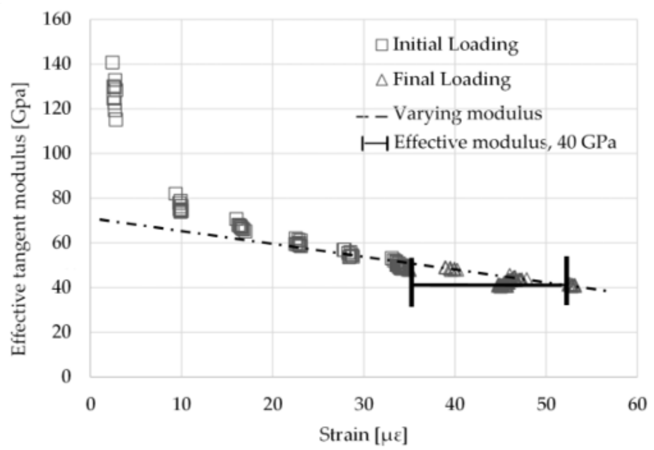


Figure 3. Effective pile tangent stiffness during working and extended pile loading tests from VWSG (1 m below the O-Cell).

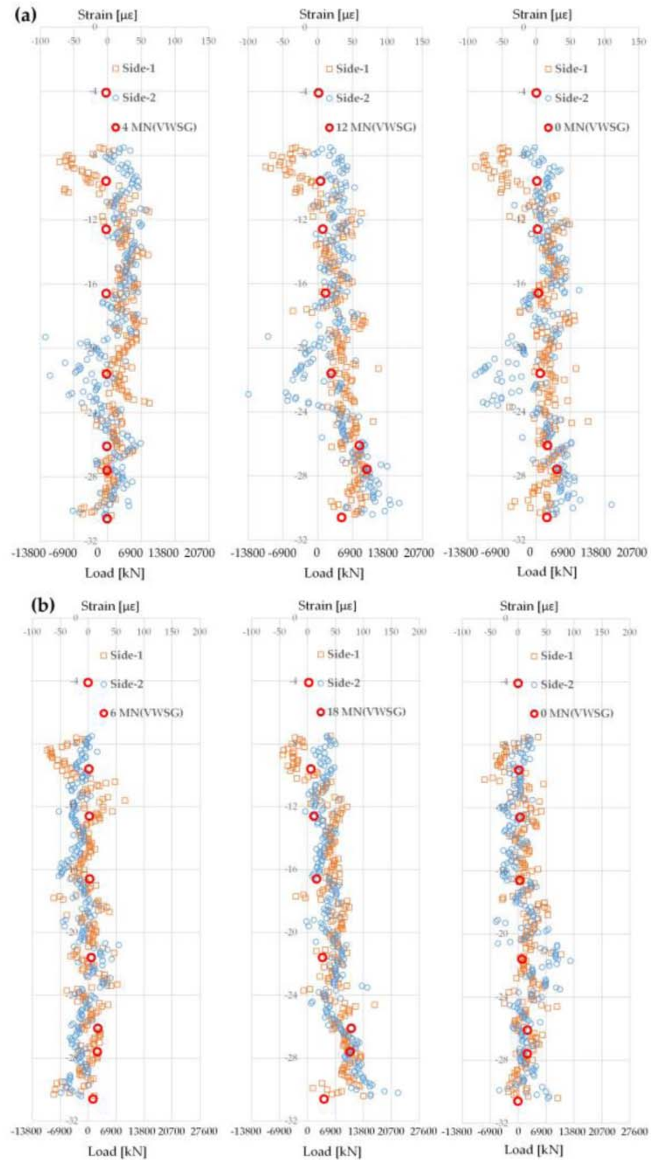


Figure 4. Comparison of strain and load measurement from OFS and VWSG along pile shaft from the two loading cycles: (a) loading cycle 1; (b) Loading cycle 2.

Strain measurement collected during the test includes two VWSGs at eight different levels and two sections of OFS strain cable along the pile shaft as indicated in Figure 1. From the eight load steps in the first loading cycle, Figure 4(a) selects four representative profiles. The two sets of independent instrumentation have shown agreeable matches at each loading phase. The strain profiles in the first loading cycle show that the load imposed from the O-Cell was gradually mobilising the pile shaft, although the initial 4 MN hardly mobilised any pile shaft. The movement of the O-Cell plates in Figure 2 also implies that the initial movement from the O-Cell mobilised primarily the end bearing capacity rather than the shaft and the magnitude of downward movement from the O-Cell plates agrees with the O-Cell expansion. The averaged shaft friction mobilised with 12 MN of load reached 187 kPa for the Thanet sand as shown in Figure 5.

The pile was unloaded prior to the second loading cycle, however, the strain profile in Figure 4(b) still shows a certain level of residual strain from the first loading cycle at the bottom of the pile section. Strain profiles were offset using the residual strain profile as a new baseline in order to examine more closely the changes induced by the load in the second cycle in Figure 4(b).

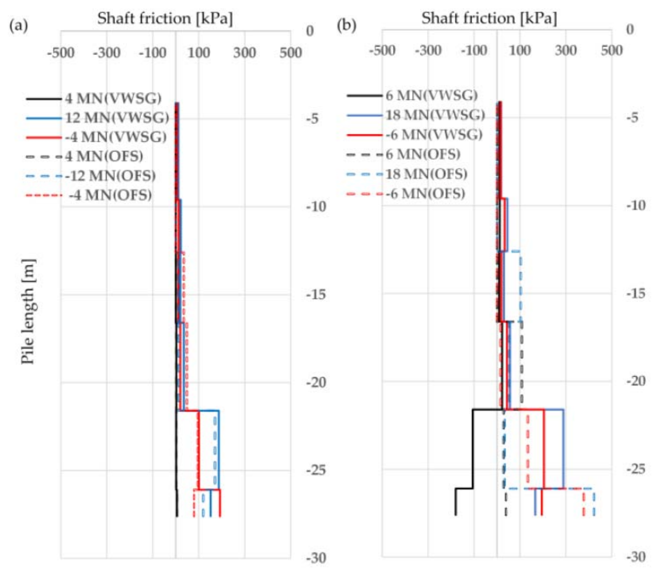


Figure 5. Calculated shaft friction from two loading cycle and the design value: (a) shaft friction from the first loading cycle; (b) shaft friction from the second loading cycle.

The pile shaft friction was estimated from the selected load profiles and is summarised in Figure 5 to evaluate the pile bearing capacity. As a working pile, it was only tested up to 82% of DVL along the pile shaft compared to the DVL + 50% SWL for conventional load test to minimise the risk of damage. The adjusted ICE SPERW test accounts for the two directional jack load from both the upward load along the shaft and downward load to the pile base with a maximum of 0.56 mm movement at the pile head and 5.67 mm at the pile base. The maximum shaft friction mobilised in the Thanet sand and Lambeth Group reached 187 KPa with 12 MN of load, and 240 KPa with 18 MN of load along the pile shaft.

The strain profiles reported by OFS tend to vary slightly in the London Clay compared with VWSG, this is mainly due to the resolution and repeatability of the BOTDR analyser. Strain measurement reported from the OFS system tends to fluctuate within relatively small strain regime (typically ±50 με) depending on the performance of the system.

CONCLUSION

The comparison between the optical fibre strain sensing measurements and the data obtained from the VWSGs shows good agreement between the two sets of data at the different stages of the test. The discrete nature of the measurements from the VWSGs imposes some amount of doubt on their reliability in fully evaluating pile performance, whereas the continuous nature of the optical fibre data has made it possible to understand the development of strain along the whole length of the pile and improves the confidence in the analysis.

Both sensing systems have successfully captured the loading features of the Osterberg test at the early loading phase of the test. Pile end bearing capacity was mobilised in advance of the shaft resistance as the applied load will need to overcome the weight of the pile prior to uplifting the pile. The two independent sensing systems have captured a zone of low friction at a level of 5 m and 15 m, whereas the majority of the load was mobilised by the skin friction between 20 m – 30 m along the pile shaft. The data from the optical fibre strain measurements suggested slightly lower shaft resistance compared to the data from the VWSGs. As the VWSGs strain data consisted only of discrete points at a distance of some metres apart, it was only possible to calculate the average strain gradient (which is related to the mobilised shaft friction) between the points and hence only an averaged value of shaft resistance could be calculated.

ACKNOWLEDGEMENT

The success of the Osterberg Cell test carried out, in accordance with the working test pile procedure, devised by Cementation Skanska Ltd Design Team, on this contract was achieved through effective collaboration between all project parties including Fugro Load Test and University of Cambridge. Accordingly the authors also wish to thank Cambridge University for their cooperation throughout the installation as well as reviewing and comparing results.

REFERENCES

Bennett, P. J., Klar, A., Vorster, T. E. B., Choy, C. K., Mohammad, H., & Soga, K. 2006. Distributed optical fibre strain sensing in piles. *The International Conference on the Reuse of Foundations for Urban Sites*.

Bourne-Webb, P. J., Amatya, B., Soga, K., Amis, T., Davidson, C., & Payne, P. 2009. Energy pile test at Lambeth College, London: geotechnical and thermodynamic aspects of pile response to heat cycles. *Geotechnique*, 59(3), 237–248.

Fellenius, B. H. 2001. From strain measurements to load in an instrumented pile. *Geotechnical news magzine*, 35–38.

Insitute of Civil Engineers. 2007. *ICE specification for piling and embedded retaining walls*, *Second edition*.

Klar, A., Bennett, P. J., Soga, K., Mair, R. J., Tester, P., Fernie, R., Torp-Petersors, G. 2006. Distributed strain measurement for pile foundations. *Proceedings of the Institution of Civil Engineers: Geotechnical Engineering*, 159(3), 135–144.

Mohamad, H., Bennett, P. J., Soga, K., Klar, A., & Pellow, A. 2007. Distributed Optical Fiber Strain Sensing in a Secant Piled Wall. *7th FMGM 2007, (Fmgm)*, 1–12.

Ohno, H., Naruse, H., Kihara, M., & Shimada, A. 2001. Industrial applications of the BOTDR optical fibre strain sensor. *Optical fiber technology*, 7, 45–64.

Thévenaz, L. 2006. Review and Progress on Distributed Fibre Sensing. Optical Fiber Sensors.

Thevenaz, L., Nikles, M., & Fellay, A. 1998. Applications of distributed Brillouin fiber sensing. *Proc. SPIE*, 3407, 374–381.

Troughton, V M, Stocker, M. 1996. Base and Shaft Grouted Piles, Proc. *ICE Geotechnical Engineering*, 119, 186-192.

The geology and geotechnical properties of the Thanet Sand Formation – an update from the Crossrail Project

Les propriétés géologiques et géotechniques de la formation sableuse « Thanet Sand » - une mise à jour issue du projet Crossrail

C.O. Menkiti, J.A. Davis, K. Semertzidou, C.O.R. Abbireddy, D.W Hight, J.D. Williams and M. Black

ABSTRACT : Crossrail will provide a high frequency, high capacity train service serving 40 stations and linking Reading and Heathrow to Shenfield and Abbey Wood. The central section is underground, at up to 40m depth, comprising 2x 6.8m external diameter bored tunnels over a 21km length, and 9 stations. The tunnels encounter or are influenced by the Thanet Sand Formation over a wide area, from shallow exposures in the east to deep conditions in the west. This paper presents an update of the geology and geotechnical properties of the Thanet Sand, interpreting a large database of information on index properties, strength, stiffness, permeability and in situ stresses obtained from ground investigations involving high quality laboratory and in-situ tests, augmented by experience from construction. The influence of depth of cover on properties is examined. Subtle variations in soil properties, such as changes in grain size near the base of the layer, have important implications for construction processes, such as dewatering and piling; these are explored. The paper augments earlier work by Ventouras and Coop (2009) and provides information for other projects within these sediments. How do reservoir sedimentation and appropriate management techniques affect operations of dams and hydroelectric facilities? The authors cover the topic and provide illustrative case studies, including the 2,100 MW Aswan High Dam in Egypt.

1 INTRODUCTION

Crossrail is one of the most significant infrastructure projects undertaken in the UK with a projected usage of 200 million journeys/ year. It will provide a high capacity train service operating at a peak frequency of 24 trains per hour and bringing an extra 1.5 million people within 45 minutes of central London. The central underground section is tunnelled to pass beneath the built up city and to avoid existing infrastructure such as piles and metro tunnels (Figures 1 & 2). Tunnelling and station excavations of up to 40m depth have been necessary, deeper than previous infrastructure works in London. As a result of the increased depth and extensive lateral extent, the Crossrail works encounter or are influenced by the Thanet Sand (TS) Formation over a wide area, from shallow exposures in the east, where its base is at a depth of 18m or less, to deep conditions in the west where its base is 40m deep or more (Figure 1).

In London, surface exposure of the TS Formation is limited. As a result, there has been limited opportunity for detailed study (e.g. Ventouras & Coop 2009). Yet it is a stratum of important engineering and financial significance, being part of the principal aquifer of London and increasingly being a medium for tunnelling and piling as infrastructure goes deeper underground and spreads outwards from the city centre. Crossrail offers, therefore, a unique opportunity to improve our understanding of the TS. Since 2000, high quality drilling and interpretation of some 372 new boreholes, mostly for the project, but including some third party boreholes, have provided a wealth of information.

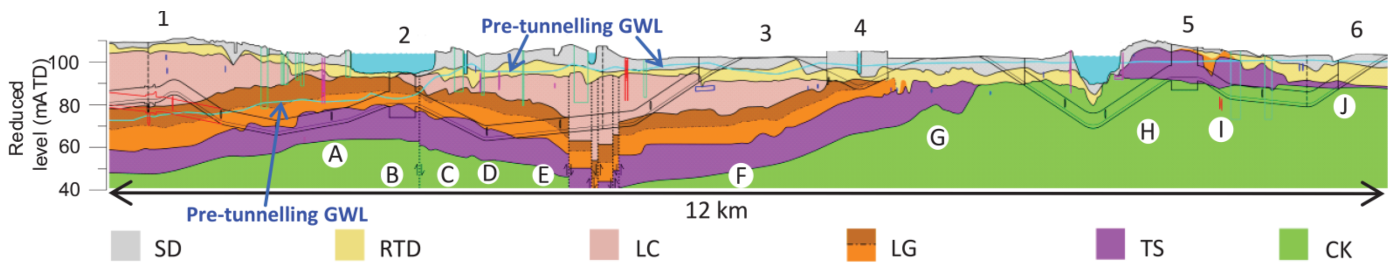


Figure 1. Geological section along southeast branch of the Crossrail tunnel alignment; 1 Stepney Green Junction, 2 Canary Wharf Station (aka Isles of Dogs Station), 3 Custom House, 4 Connaught Tunnel, 5 Woolwich Station, 6 Plumpstead Portal. Geological sequence shown (top to bottom): Superficial Deposits (SD=Made Ground, Alluvium, Langley Silt), River Terrace Deposits (RTD), London Clay (LC), Upper Lambeth Group (LG, dark brown), Lower Lambeth Group (LG, light brown), Thanet Sand (TS) and Chalk (CK). GWL = Groundwater Level in the TS and CK.

This, augmented by observed performance during tunnel construction, has allowed a significant improvement in the interpretation of the geotechnical parameters and engineering behaviour of the Thanet Sand in the London area. This is the focus of this paper.

2 GEOLOGY AND HYDROGEOLOLOGY

The TS Formation in London is a sequence of upwardly-coarsening, fine-grained, green-grey or greybrown sand, within the Palaeocene series of the Palaeogene period. It was laid down about 58 million years ago in a coastal inter-shelf environment adjacent to an arid Chalk upland to the northwest.

The TS overlies the Chalk in the London area and generally thins to the west, mainly due to later uplift, tilting to the southeast and erosion. The average thickness in the Crossrail area is 15m. The lower section of the TS formation has higher fines content in many locations and is a clayey SAND or sandy CLAY. The upper boundary of the TS is an erosional surface and is unconformable with the overlying Upnor Formation (UF) of the Lambeth Group (LG). This boundary is intensely bioturbated (i.e. reworked by animals and plants) and can be very diffuse. This interface can therefore be difficult to distinguish, also because the UF can have a similar lithology to the TS. For the Crossrail Project and the interpretation presented in this paper, the presence of pebbles, obvious glauconite, shells and clay/ silt laminae is carefully checked for at the boundary zone in the logging process. Where these occur, the zone is classified as UF not TS. (Glauconite occurs in the TS too, but in very low concentrations at the TS-UF interface relative to concentrations found in the UF.)

The basal unit of the TS Formation in London is the Bullhead Beds - a conglomerate of angular to rounded coarse flint gravel and nodular flint in a matrix of clayey, fine to coarse sand. Flint nodules can be up to 500mm in size and are difficult to recover in boreholes. The Bullhead Beds' thickness as inferred from Crossrail boreholes is 0.1 – 1.2m.

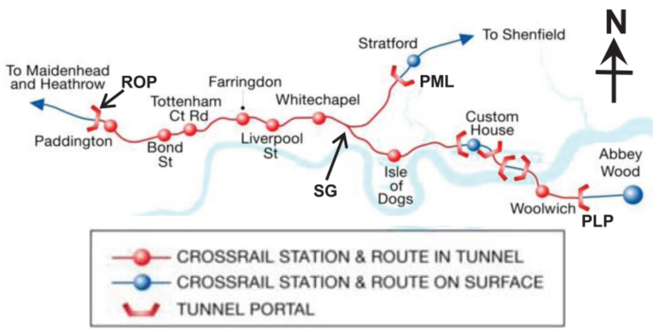


Figure 2. Plan alignment of Crossrail tunnelled section involving 2 x 21km, 6.8m outer diameter running tunnels. ROP = Royal Oak Portal, SG = Stepney Green Junction, PML = Pudding Mill Lane Portal & PLP = Plumpstead Portal.

At the eastern end of the alignment, where the TS is shallow, the cover of Lambeth Group and London Clay is absent (Figure 1). The TS in this zone was observed to be weathered, where it is subjected to tidal variations in ground water level. Weathering, which can extend through the full thickness of the TS, occurs as light brown or orange-yellow staining; weathering was observed up to 1.5km from the current River Thames river wall.

The TS and Chalk comprise the principal aquifer in London, called the deep aquifer. Over most of London, it is separated from the shallow aquifer formed by the River Terrace Deposits (RTD) and Made Ground by the low permeability London Clay and Lambeth Group clays (e.g. Figure 1 Locations A to F). The TS and Chalk are in hydraulic connection and have a depressed groundwater table due to historic pumping over the last 200 years. To the east, where the TS is shallow, the upper and lower aquifers merge and the TS is in hydraulic connectivity with the RTD (Locations G to J). Occasionally, deep drift-filled hollows, such as the Blackwall hollow (originally described by Berry 1979), penetrate down to the deep aquifer and can locally provide vertical connectivity between the shallow and deep aquifers. This was evidenced on Crossrail as a 1m amplitude tidal response in the TS and Chalk near Blackwall, despite a clay cover of 20 – 30m between the two aquifers outside this drift-filled hollow.

3 MINERALOGY, FABRIC AND GRADATION

The sand grains comprise sub-angular quartz (70-85%) with some glauconite and feldspar. Montmorillonite is dominant within the clay fraction. The orange staining in the weathered TS is due to haematite and goethite formed by weathering processes. From thin section studies, Ventouras & Coop (2009) report a dense fabric that is not locked or cemented. This is consistent with the strength envelopes discussed in Section 4.3.

Figures 3 & 4 show particle size information for the TS. A consistent and uniform grading is shown across London, along the Crossrail alignment. The bottom 5 – 6m of the stratum has higher fines content and plots towards the upper bound line in Figure 3. Typically clay content of the TS ranges from 0 - 20% and fines content from 0 to 70%. The southeast branch of the alignment (SG to PLP in Figure 2) has more fines and clay in the basal layer, with clay content in the bottom 2m reaching 35% - 40% (Figure 4). Nicholson et al. (2002) measured a similar trend at Canary Wharf.

4 GEOTECHNICAL PARAMETERS

4.1 Index properties

Bulk density from 330 tests on "undisturbed" rotary core samples was 1.88 Mg/m3 with a standard deviation of 0.09 Mg/m^3. Average bulk density in-situ is likely to be around 1.9 Mg/m^3 due to a possible slight bias from partial desaturation of the rotary cores. The specific gravity was measured as 2.65 +/- 0.1. The relative density from sub-samples trimmed from the centre of "undisturbed" rotary core samples was 84% +/-9%. For this determination, the minimum density was determined according to Kolbuszewski (1948) and the maximum density using a vibratory hammer in a CBR mould.

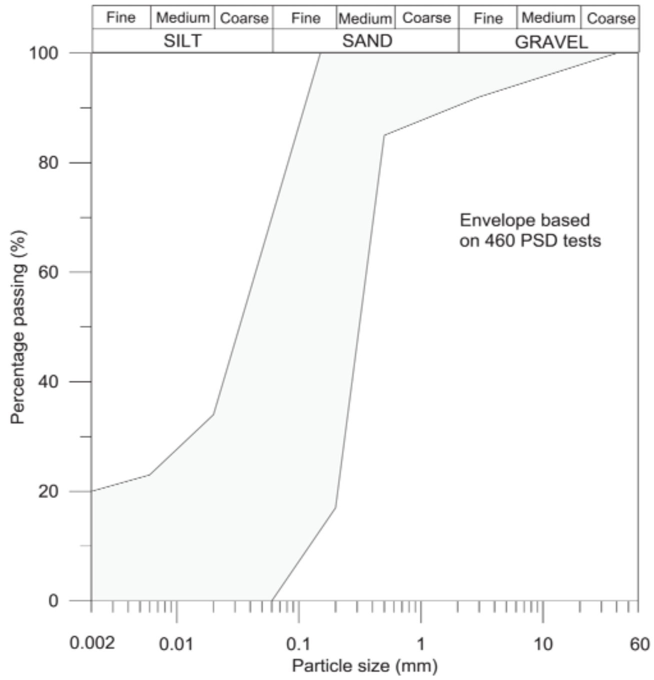


Figure 3. Particle size distributions

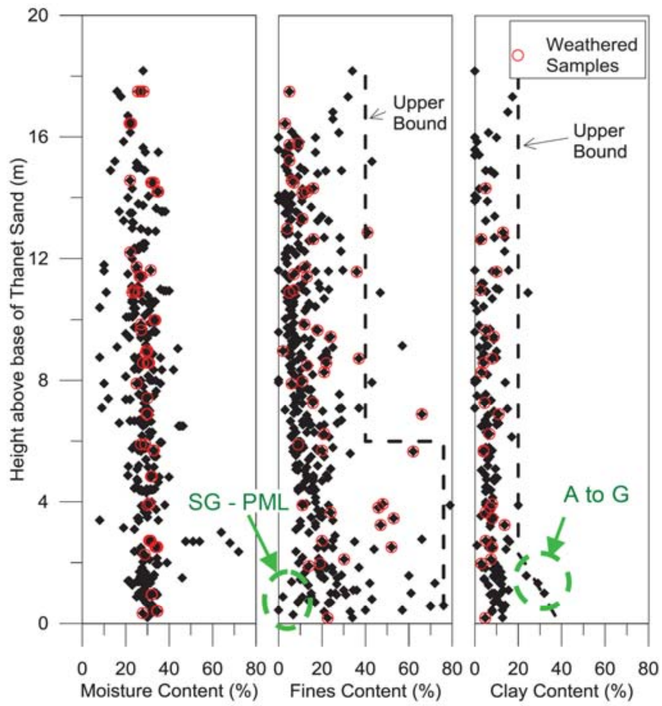


Figure 4. Index properties plotted as height above base of TS. Indicative upper bound lines shown. Fines content in the lower 2m, with values of 10% or less are from the northeast branch (SG to PML in Figure 2). The high clay content (20 – 40%) shown above in the bottom 2m are from the southeast branch, Zones A to G in Figure 1. Moisture content from "undisturbed" rotary core samples.

4.2 Strength

SPT values measured on Crossrail varied from 20 to 200 in the upper sandier layers and 40 to 140 in the bottom, silty/

clayey 6 to 8m. There is some evidence for a higher mean value in the upper sandier zones than in the lower clayey sections.

The effective stress strength parameters from a large number of shearbox and drained and undrained triaxial compression and extension tests are shown in Figures 5 and 6. No cohesion was seen. A curved failure envelope with peak friction angle in compression (φ'_p) varying with stress level was observed. At low stress levels of up to 400kPa, φ'_p was up to 42° and reduced to 37° to 39° for stress levels of 400 to 700kPa.

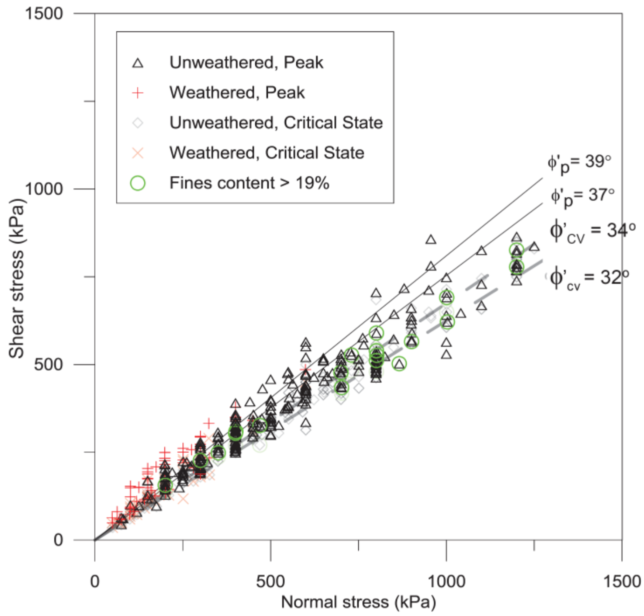


Figure 5. Direct shear box tests on "undisturbed" rotary core samples and disturbed samples tamped to the in-situ density.

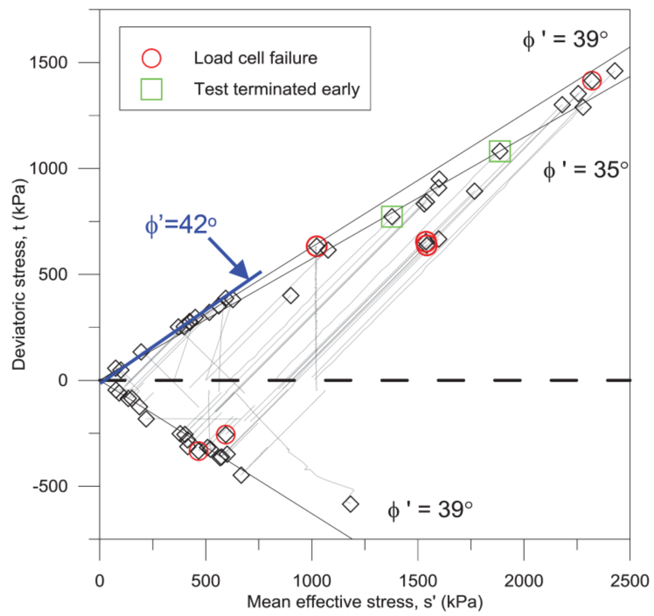


Figure 6. Stress paths and peak strength from shear stage of triaxial tests on "undisturbed" rotary core samples. Samples were consolidated isotropically and anisotropically to in situ conditions and then sheared. Some tests on deep TS samples were terminated early because the load cell reached capacity. In a few tests, the load cell was overloaded and failed in compression or extension (connection failure).

At higher stress levels, up to 2.5MPa, φ'_p could reduce to 35°. Ventouras and Coop (2009) measured comparable values of 34.1° to 38.7° for stress levels of up to 1100kPa.

In triaxial extension, a similar peak friction angle of 39° was measured (Figure 5). This contrasts with Ventouras & Coop (2009) who measured 30° in extension for a single sample. The reason for this differing finding is not known.

Critical state friction angle was measured as 33° +/-1° from shearbox tests (Figure 5). There was no significant effect of weathering or fines content. This critical state strength measurement is consistent with the angle of repose of 33° +/-1o measured by pouring dry sand on a glass plate. It is also similar to a value of 32.3° reported by Ventouras & Coop (2009), which did not vary with stress level up to ~20MPa.

4.3 Stiffness

Stiffness degradation curves for TS were obtained from triaxial tests with local instrumentation and from in-situ pressuremeter tests. In sands, the pressuremeter tests were drained and effective stress levels increased significantly during the test. Stiffness was therefore interpreted from load-unload loops using the method of Jardine (1992) but incorporating Bellotti et al (1989) to account for the large changes in stress level. Results are shown in Figure 7. A nonlinear response with good correlation between the insitu and lab data is shown.

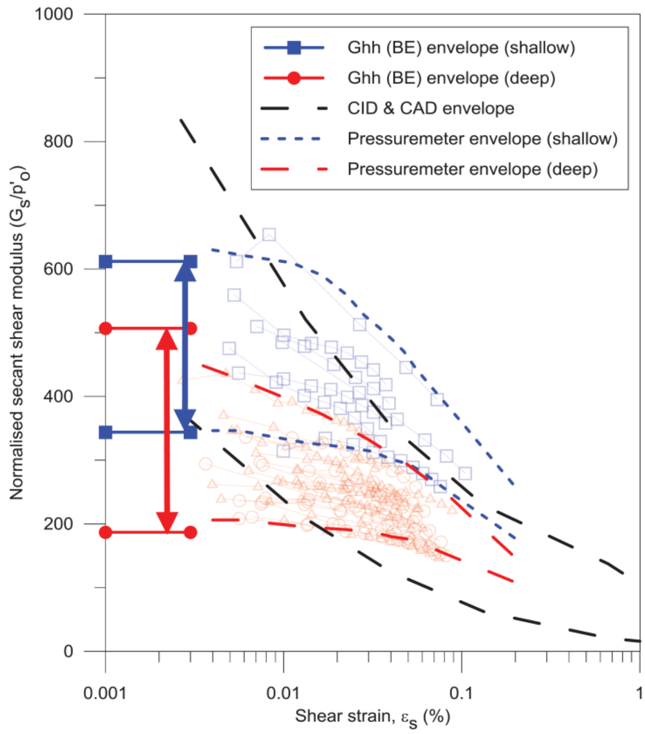


Figure 7. Stiffness degradation curves normalised by mean effective stress at start of shear (p'_o). Shallow TS have a base at depths up to 18m (e.g. Locations H to J in Figure 1). Deep TS have a base at depths of 40m to 60m (e.g. Locations A to F in Figure 1).

The shallow TS shows a higher normalised stiffness, possibly due to a higher degree of over consolidation. No effect of weathering on stiffness was observed. The pressuremeter test shears the soil in a horizontal plane. The horizontal small strain shear stiffness, G_{hh}, from good quality bender element tests on triaxial samples are compared to the pressuremeter data in Figure 7 and can be seen to match very well.

4.4 Ko profile

Data on the in-situ stresses in the TS is presented in Figure 8 as Ko, the coefficient of earth pressure at rest. Ko was derived from high quality in-situ pressuremeter tests and theoretical modelling (Burland et al. 1979) that reproduced the last significant geological processes, namely deposition of the full London Clay thickness, followed by its erosion to current local thickness and then deposition of the RTD and SD layers and the pre-tunnelling groundwater conditions (see Figure 1). Profiles for the deep and shallow TS are given together with a nominal design line.

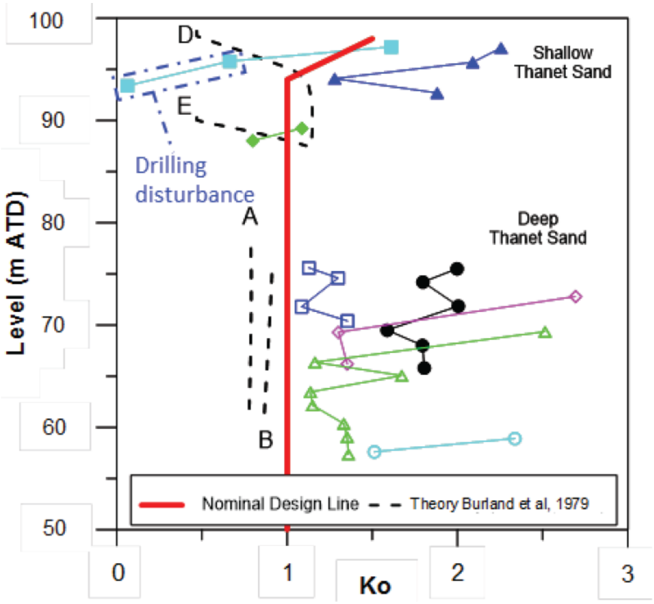


Figure 8. Coefficient of earth pressure at rest (Ko) measured at boreholes in TS using pressuremeters with displacement measuring feeler arms (self-boring & high pressure dilatometer types). Theoretical values derived for local conditions at Locations B & C (deep TS) and H & J (shallow TS), see Figure 1. Levels; 100m ATD (metres above tunnel datum) = 0m Above Ordnance Datum.

4.5 Permeability

The permeability of the TS was determined from various means as shown in Figure 9. The most reliable information on mass permeability was from pumping tests at stations and portals where dewatering was necessary for construction. Horizontal permeability of the TS was measured to be about 10-5 to10^{-6} m/s. The higher value may reflect nearby geological complexities such as faulting and drift filled hollows. The clayey basal units of the TS, where it exists, has a lower permeability of about 10^{-7} m/s. This reduces the vertical permeability of the whole TS formation. This is illustrated by experience from dewatering at Canary Wharf area, which has been ongoing for several years for various projects with abstraction from the CK and under-drainage of the overlying TS. The clayey TS basal layer maintained a perched water table in the TS that slowly declined but was still sustained for 5 years.

5 OBSERVED ENGINEERING BEHAVIOUR

Nicholson et al. (2002) noted that the bearing capacity of piles founded in the TS base (where the material is a clayey sand/ sandy clay) is significantly lower than that for higher up in the stratum where the TS is a sand. This can lead to a reduction in pile capacity with depth. For tunnel boring machine works, however, the TS was observed to be benign. Typical volume losses for earth pressure balance TBM passage (full-face in TS) was 0.5% to 1% (Location A, Figure 1). For the slurry TBM, volume loss was much lower, no more than 0.25%, but the stretch in fullface TS was limited (Location I, Figure 1).

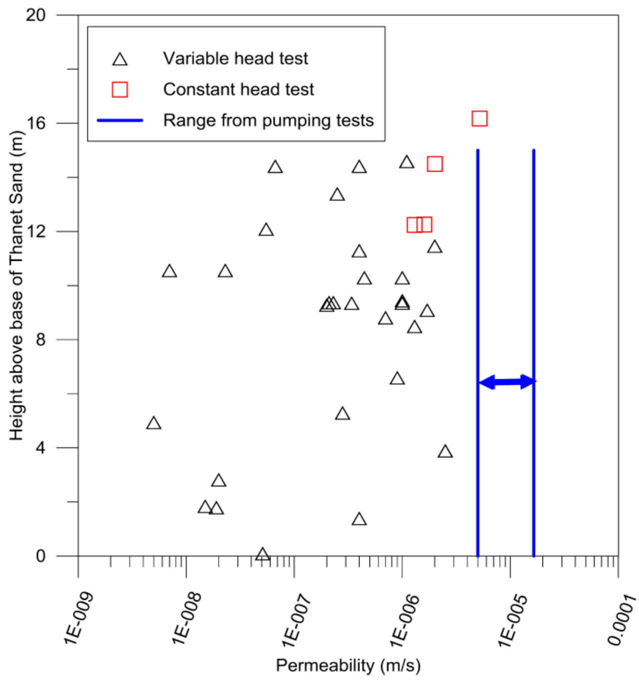


Figure 9. Permeability from laboratory tests (constant head) and in-situ tests (variable head tests in piezometers and field pumping tests).

5 OBSERVED ENGINEERING BEHAVIOUR

Nicholson et al. (2002) noted that the bearing capacity of piles founded in the TS base (where the material is a clayey sand/ sandy clay) is significantly lower than that for higher up in the stratum where the TS is a sand. This can lead to a reduction in pile capacity with depth. For tunnel boring machine works, however, the TS was observed to be benign. Typical volume losses for earth pressure balance TBM passage (full-face in TS) was 0.5% to 1% (Location A, Figure 1). For the slurry TBM, volume loss was much lower, no more than 0.25%, but the stretch in fullface TS was limited (Location I, Figure 1).

Suitable dewatering was required for open face tunnelling, but this was achievable. The TS could retain suctions from lowering of the water table. When augmented with vacuum wells, vertical faces with good stand-up time were obtained, which facilitated open face construction (Figure 10).

6 CONCLUSIONS

The unique opportunity provided by the Crossrail project has been used to investigate the TS Formation and update the geotechnical parameters and construction experience to date. This could be useful for other projects in similar ground. The TS was found to be a dense competent sand, with variations in fines content that result in differing engineering responses. There was no discernible effect of weathering on particle size distribution, bulk density, strength and stiffness.

REFERENCES

Bellotti, R. Ghionna, V. Jamiolkowski, M. Robertson, P. K. & Peterson, R. W. 1989. Interpretation of moduli from self-boring pressuremeter tests in sand. *Geotechnique* **39**, No.2, 269-292.

Berry, F. G. 1979. Late Quaternary scour-hollows and related features in central London. *Quarterly Journal of Engineering Geology and Hydrogeology*. Vol. **12**, 9-29.

Burland, J. B. Simpson, B. & St. John, H. D. 1979. Movements around excavations in London Clay. *Proc. 7th Eur. Conf. Soil Mech* **1**, 13-29, BGA, Brighton

Figure 10. Photograph of TS in excavation for Cross Passage 13 (point D in Figure 1). The upper TS stood as a stable face with clear tool indentations in an open excavation, with vacuum well facilitated dewatering. Note UF-TS interface.

Jardine, R.J. 1992. Some observations on the kinematic nature of soil stiffness. *Soils and Foundations*, **32**, No. 2, 111-124.

Kolbuszewski, J. 1948. An experimental study of the maximum and minimum porosities of sands. *Proc. 2nd ICSMFE* , **1**, 158-165, Rotterdam.

Nicholson, D. Chapman, T. & Morrison P. 2002). Pressuremeter proves its worth in London’s Docklands. *Ground Engineering*, March 32-34.

Ventouras, K. & Coop, M. R. 2009. On the behaviour of Thanet Sand: an example of an uncemented natural sand. *Geotechnique* **59**, No. **9**, 727-738.

Research into the effect of tunnelling on existing tunnels

Etude des effets de la percée de tunnels à proximité de tunnels existants

J.R. Standing, D.M. Potts, R. Vollum, J.B. Burland, J.B.Y. Yu, M.S.P. Wan and V. Avgerinos

ABSTRACT Increasing demands for providing transport systems in the urban environment has led to many tunnelling projects being undertaken worldwide. Many of the cities where new tunnels are to be constructed already have a comprehensive underground network of tunnels for both transport and services. New tunnels often have to be aligned beneath these and frequently there are concerns that their construction may cause unacceptable deformations of the existing tunnels, potentially hindering their serviceability and in the extreme threatening their stability. The Crossrail project, currently underway in London, involves tunnelling beneath numerous existing tunnels. It therefore has provided a great opportunity to study this complex boundary value problem. This paper describes the philosophy behind a comprehensive research project, run in conjunction with the Crossrail construction, which has an emphasis on the response of older tunnels lined with grey cast iron segments. There is a focus on how the Central Line tunnels responded to new twin tunnel construction beneath them. The five main strands of the research are: field monitoring within and around the existing tunnels; numerical analyses of the field conditions; structural testing of a half-scale grey cast iron segmental ring; numerical analyses of the ring and two-segment tests performed; advanced laboratory testing of London Clay samples taken during installation of field instrumentation. These activities link into each other. Some preliminary results are presented and the main finding to date are summarised.

1 INTRODUCTION

Urban expansion and the need to provide efficient transport sytems has led to many underground systems being developed in cities worldwide. In many cases comprehensive underground networks already exist and so new tunnels have to be constructed deeper and consequently pass beneath exisiting tunnels. As tunnel construction inevitably causes ground deformation, there is always concern that these might adversely affect the existing tunnels. There are two issues: first the stability of the tunnel and second the tolerable deformations to which it can be subjected. Stability would be affected only in extreme cases after significant deformations and so understanding the shape of existing tunnels *in situ* and how they develop as a consequence of nearby underground excavation is of great interest. Most existing tunnels after their construction tend to 'squat', i.e. their horizontal diameter is greater than the vertical. There is very little known about the state of stress and bending moments within the tunnel linings (e.g. how close they are to yielding) and how these might change if the tunnel is deformed further. When the tunnels are used for running trains it is essential that the operational kinematic envelope required is not encroached upon, otherwise rolling stock might be damaged and it may be necessary to impose speed restrictions, both leading to major costs through repair and delays.

Crossrail is a major new railway transport system with a significant length running east-west through central London. The new 7.1-m diameter tunnels, constructed mostly with earth pressure balance tunnel boring machines (EPB TBMs), pass beneath numerous existing tunnels. Clearly, serious consideration was given to how the new tunnels would affect them and whether mitigation measures should be implemented to help safeguard them. Historically quite different approaches have been taken with in some cases bolts connecting segments being loosened or removed (e.g. Moss & Bowers 2006) and in others tightened (e.g. Kimmance et al. 1996). The former helps minimise additional bending moments being generated but allowing displacements to develop while the latter has the converse effect.

In view of the numerous uncertainties and the very serious implications of disruptions to the railway operation, Imperial College London have undertaken a major research project to investigate the influence of tunnelling on exisiting tunnels. The research was primarily funded through the UK Engineering and Physical Science Research Council (EPSRC) with major contributions from Crossrail Ltd and Morgan Sindall and collaboration with London Underground Ltd (LUL). The proposal to EPSRC was submitted in 2009 after two years preparatory work with the collaborating partners and funding was granted the same year after the usual review process. The grant expired in 2014 after running for four and half years: all aspects of the proposed work were successfully completed. Numerous publications are now underway (and some already complete: Fearnhead et al. 2014; Wan & Standing 2014a & b; Yu et al. 2014) to disseminate to academia and industry the findings from this study. This paper describes the scope of the study and reports some initial findings.

2 RESEARCH SCOPE

From the outset it was intended that the scope would cover field monitoring, structural testing and numerical analysis. A suitable location for monitoring was identified by Crossrail where the new tunnels were to pass beneath the LUL Central Line tunnels under Bayswater Road just north of Hyde Park. The existing tunnels were constructed at the end of the nineteenth century and were built using segmental grey cast iron linings. The possibility of structural testing of a number of lining materials was initially considered but it was soon realised that this was not practicable. In view of the intention to monitor the Central Line tunnel and as there are considerable uncertainties about the response of this type of lining, a decision was made to focus on grey cast iron. Numerical analyses were to be used primarily to model the field conditions. The bespoke in-house Imperial College Finite Element Program (ICFEP) was to be used throughout. Additionally, comprehensive analyses were performed to model the segments tested in the structures laboratory. The results provided great insight into the stress distributions within the segments and helped with planning the layout of strain gauges installed on the ring tested. Another component of the study was to perform advanced laboratory testing on high quality rotary samples taken at Hyde Park during installation of subsurface field instrumentation. Parameters from these tests can then be used for refining the input data for numerical analyses relating to field conditions.

Thus there were five major aspects of the research with many links between them. These five strands are now discussed in more detail.

2.1 Laboratory structural testing

Following the decision to focus on grey cast iron segments, the first action was to select a suitable iron composition to replicate typical materials cast at about the time when the Central Line tunnels were constructed. LUL archive records were sourced and a suitable mixture for smelting was selected. Earlier mixes for cast iron had greater concentrations of phospherous, leading to a more brittle response of the iron. Morgan Sindall liaised with the foundry (Russell Ductile Castings) and procured the segments. Segment dimensions were chosen to be at half-scale of the prototype. In this way accurate proportionality was achieved, the governing thickness being that of the skin. Twelve segments were cast, sufficient for two rings. To avoid complications and the need for additional moulds, no key piece was made: the segments were thus all identical. The stiffness of cast iron degrades with progressive loading and unloading cycles beyond the yield stress. To determine the yield stress level (and associated strains) and the effect of reducing stiffness, a number of coupon samples cast at the same time as the segments, were tested. This was an essential exercise to ensure that the segments were always kept within their elastic range during the preliminary tests. In this way interpretation of the multiple strain gauges was greatly facilitated and could be made with confidence.

The primary intention with testing was to deform the ring to similar shapes observed *in situ* both prior to and after nearby underground excavation. It was decided that the most expedient way of achieving this was to apply loads through actuators rather than trying to achieve the same with soil. The ring was assembled in a horizontal plane on a structural floor with actuators attached to a steel reaction ring outside the half-scale model test ring (Figure 1) with three actuators per segment. Each actuator bore onto a spreader pad via a load cell to help distribute the load as a uniform radial stress. The ring rested on rollerbearing pads to minimise friction with the floor. The ring was deformed using a combination of computer activated load and displacement control. Initially a uniform radial stress was applied to the ring via all actuators and then some were held at constant load while others were displaced to produce essentially elliptical forms. Multiple tests were performed to assess the effects of differing initial radial stresses, representing four typical tunnel depths (to about 25 m maximum) and various bolt forces (5, 7.5 and 10 kN). The influence of installing tar-infused hemp grommets within the bolt holes was also investigated.

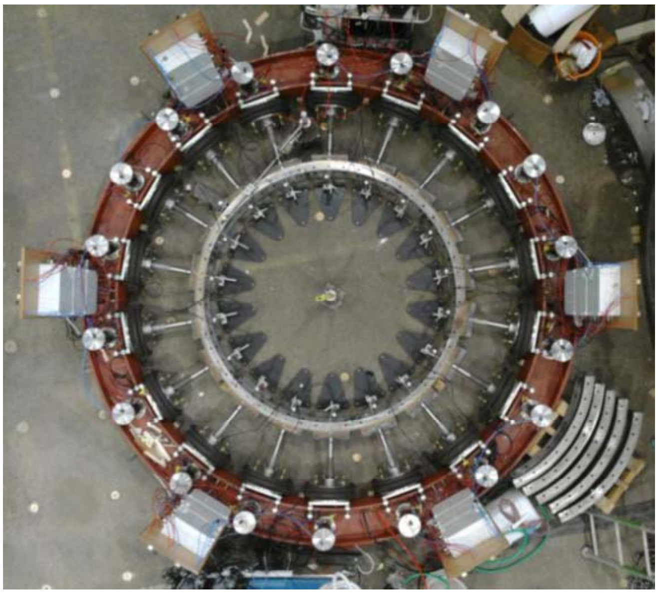


Figure 1. View from above of the test set-up for loading the halfscale model segmental ring (larger outer ring is the reaction ring)

Extensive instrumentation was installed on the segments in the form of strain gauges, displacement transducers across joints and instrumented bolts. In this way, global and local joint responses of a bolted segmental cast iron lining were studied experimentally and the internal actions relating to a particular deformed shape could be measured. The design and development of the bespoke loading facilities from scratch was a major contribution of this research into the behaviour of bolted segmental linings. This work was led by Dr Jessica Yu (Yu 2014). Several major conclusions have come from the work. At high hoop force stress levels, the bolted segmental ring behaved as a continuous ring while at low levels joint stiffness values started to reduce allowing greater articulation. Additionally, for the small distortions imposed, the presence of compressive hoop force renders the magnitude of bolt preload insignificant in terms of influencing bolted segmental lining behaviour. This suggests that there may not be much benefit in either tightening or loosening bolts as mitigating measures to excavation-induced ground movements. Other findings will be reported in forthcoming publications.

Following the extensive tests performed under elastic conditions, two tests were performed (by Dr Sheida Afshan), imposing maximum displacements of about 40 mm. The intention was to investigate the ring response as failure was approached. In the second test, failure occurred within the circumferential flange, close to its junction with the radial flange.

Prior to the full-ring tests, a careful review of existing experimental data (Thomas 1977) facilitated an initial estimate of joint bending moment capacity. A series of two-segment tests of varying bolt preloads was conducted and the results interpreted under the assumption of elasticity. As the conditions of the two-segment test were statically determinate, the interpretation of the instrumentation and estimation of the bending moment could be compared against analytical equations. This proved useful in giving confidence that the methods used to interpret the instrumentation, especially the strain gauge readings, were appropriate. The same methods of interpretation were used in the full-ring tests.

2.2 Numerical analysis of two-segment tests

A 3-D finite element model using ICFEP was developed by Dr Katerina Tsiampousi in conjunction with the two-segment test laboratory experiment. A linear elastic model was implemented for the iron, while joint opening was allowed in modelling the connections. Results from the test indicated regions where greater element refinement was necessary in the FE mesh, as well as the level of detail required, e.g. the inclusion of the caulking groove. The main series of tests showed that the stiffness of the bolting system assumed in the FE model was too high. The actual bolting system of bolts, nuts, washers, and the contact between them rendered the stiffness of the system several times lower than the stiffness of the mild steel bolt. Since the stiffness of the bolting system affected how the FE model predicted the deflection of the longitudinal flange, this was a valuable finding for future FE modelling of segmental ring behaviour.

In general the FE predictions compared well with the laboratory measurements. The FE model proved helpful in providing a guide to the behaviour of the two-segment arch beyond the loading conditions tested in the laboratory. An important prediction was that when the joint was subjected to negative bending in the FE model, all three bolts had similar increases in bolt load and the joint opened uniformly along the extrados, i.e. the displacement at the outer edge was predicted to be similar to the displacement at the middle of the segment. This led to a revision of the joint moment capacity estimation for the full-ring test where joints were subjected to both positive and negative bending.

Additionally, the FE analyses allowed an interrogation of the principal tensile and compressive stresses in the longitudinal flange. Since the analyses were linear elastic the results could only provide a guide to the capacity of the joint. Nonetheless by limiting the tensile stresses in the longitudinal flange as predicted by the FE simulations to below the ultimate tensile capacity of cast iron, it was shown that the initial estimate of joint moment capacity was reasonable. Non-linear analysis would be necessary to determine the true capacity of the joint.

2.3 Field monitoring

There were two aspects of field monitoring. One involved monitoring existing tunnels and the other the ground above and around them.

Prior to monitoring the Central Line tunnels there was an opportunity to instrument segments in one of the station tunnels at Tottenham Court Road during its upgrading as part of the Crossrail works. Some of the instruments and methods to be used in the Central Line tunnel monitoring were tested as part of the exercise. The linings instrumented were removed as part of the works and so changes in stress from before to after dismantling allowed estimates to be made of the degree of overburden acting on them. The magnitude of change in strain measured using electrical and mechanical strain gauges was found to be similar to that predicted assuming full overburden unloading with a segment modulus of 100 GPa. The work is described in a recent paper (Yu et al. 2014).

A length of the eastbound Central Line tunnel running between Lancaster Gate and Marble Arch stations where the Crossrail tunnels were to be constructed beneath it (with a clearance of 4.2m and at about 40 degrees skew) was monitored. The instrumentation installed on two rings comprised numerous electrical strain gauges, displacements gauges (across longitudinal joints) and eye bolts for tape extensometer measurements. A team from ETH Zurich, under the direction of Prof. Sasha Puzrin working in collaboration with Imperial College, installed state-of-the-art optical fibre sensors circumferentially at these locations and along the affected length of the crown of the tunnel. Results from monitoring a string of electrolevel beams along the tunnel length were kindly provided by BFK (BAM Nuttall, Ferrovial Agroman and Kier Construction) to supplement the data.

Examples of the findings from this work are that the deformed shape of the tunnel lining from the tape extensometer measurements corroborated well with the mode of bending in the lining segments captured by the strain gauge measurements. Data from the optical fibre sensors suggested that longitudinal deformation along the Central Line tunnel crown occurred along the segment and not at the circumferential joints. However, those installed circumferentially were able to detect movement across the longitudinal joints as the Central Line tunnel deformed. The latter interpretations were possible with the distributed nature of the measurements using swept wavelength interferometry with a spatial resolution of about 1 cm.

Extensive surface and subsurface instrumentation was installed above and around the existing Central Line tunnels and the new Crossrail tunnels. This aspect of the work was led by Dr Michael Wan. The scope of what could be installed close to the Central Line tunnels was limited as the tunnels run beneath the busy Bayswater Road. It was more straightforward installing instrumentation around the Crossrail tunnels from within Hyde Park. The field monitoring allowed differences in the ground response to tunnelling to be observed in a greenfield condition compared with the ground close to and affected by construction of the existing tunnels and the subsequent consolidation that took place. Three arrays of surface monitoring points were installed: one along Bayswater Road and two within Hyde Park. Instruments were installed in a total of 38 boreholes to measure subsurface vertical and horizontal displacements and strains, pore water pressures and total stress changes. Lessons learnt during the extensive installation period are given along with details of the grouts used to install instruments (Wan & Standing 2014a). ETH Zurich also installed optical fibre sensors in two rod extensometer boreholes and two shallow trenches (transverse and longitudinal to the westbound Crossrail tunnel). The instrumentation layout and the relative tunnel positions are shown in Figure 2.

Mostly conventional instrumentation and precise surveying techniques were used, e.g. rod extensometers, in-place inclinometers (MEMS tilt sensors), and vibrating wire piezometers. The relatively new technique of installing multiple piezometers in a grouted borehole was adopted (Wan & Standing 2014b).

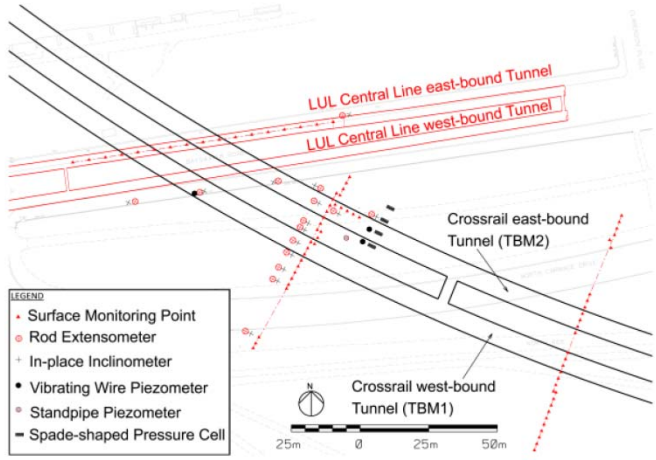


Figure 2. Plan showing relative positions of new and existing tunnels and field instrumentation layout

Field observations showed that pore pressures close to the Central Line tunnels were slightly below hydrostatic, indicating drainage into the existing tunnels and settlement troughs were wider where the existing tunnels are located. Wan (2014) gives full details of the monitoring results and their interrelation with EPB TBM progress and variables and geology.

2.4 Numerical analysis of field conditions

All analyses were undertaken using ICFEP by Dr Vasilis Avgerinos (Avgerinos 2014). There were three main aspects of the numerical analysis.

Initially a sophisticated two-surface kinematic hardening constitutive model was calibrated using advanced laboratory soil test data. It was then used to model the well-documented St James's Park Jubilee Line Extension case study (Nyren, 1998), accounting for different London Clay units. Excellent agreement with the field monitoring data was achieved for both short- and long-term responses.

The same model was used to simulate the new Crossrail tunnel construction at Hyde Park accounting for the previous stress history of the site. Again excellent agreement with the field data (Wan, 2014) was obtained even though the Crossrail tunnels are larger and constructed with a different tunnelling method (EPB vs. open-face shield at St James's Park), indicating the capability of the soil model to predict realistic soil movements from tunnelling in general.

The final stage of analysis was to model the situation at Hyde Park in 3-D. Because of the number of elements and the computing power required it was not practicable to use the sophisticated constitutive model used previously. Therefore a pre-yield nonlinear elastic small strain stiffness model coupled with a Mohr-Coulomb plastic model was adopted. Other simplications made were to assume that the Crossrail tunnels were perpendicular to the Central Line (i.e. ignoring any skew) and to model both pairs of tunnels as single tunnels. Parametric analyses were run varying factors such as EPB TBM face pressure and the longitudinal stiffness of the existing tunnel. This exercise resulted in excellent qualitative agreement with the way in which the existing tunnels distorted as the new tunnels approached and passed them. Insight was also gained for the same stages into how bending moments and lining stresses developed. Another important finding from this work was the effect of shear stresses acting on the extrados of the exisiting tunnel(s) on the bending moment distribution within the lining.

2.5 Advanced laboratory testing

High quality rotary samples were obtained from three of the boreholes made for installation of field instrumentation. These were positioned at increasing distances from the Central Line tunnels to investigate the effect of its construction on ground properties. 18 advanced triaxial tests have been performed with state-of-the art instrumentation for measuring small strains (three axial and radial locations) and cross anisotropic moduli (using bender elements). Samples were consolidated anisotropically back to their *in-situ* stresses prior to undrained shearing in compression. This work has been completed by Dr Ramtin Hosseini Kamal and Dr Khalid Al Haj.

3 SUMMARY AND CONCLUSIONS

This paper has given an overview of a major research project investigating the effect of tunnelling on exisiting tunnels. Five main, often inter-related, areas have been described and preliminary findings given and reference to publications to date. Further papers giving greater detail will be forthcoming.

ACKNOWLEDGEMENTS

The main sponsors of the research were EPSRC (EP/G063486/1), Crossrail Ltd and Morgan Sindall. There are a multitude of other people and parties whose contributions should be recognised but cannot for lack of of space: the authors are most grateful for all the help and input received from them.

REFERENCES

Avgerinos, V. 2014. *Numerical investigation of tunnelling beneath existing tunnels*. PhD thesis, Imperial College London.

Fearnhead, N. Maniscalco, K. Standing, J.R. & Wan, M.S.P. 2014. Deep excavations: monitoring mechanisms of ground displacement. *Proc. ICE – Geot. Engng.* **167**, GE 2, 117–129.

Kimmance, J.P. Lawrence, S. Hassan, O. Purchase, N.J. & Tollinger, G. 1996. Observations of deformations created in existing tunnels by adjacent and cross cutting excavations. *Proc. Int. Symp. on Geot. Aspects of Underground Constrn. in Soft Ground* (Eds: Mair & Taylor). 707–712. Taylor Francis Group. Rotterdam.

Moss, N.A. & Bowers, K.H. 2006. The effect of new tunnel construction under existing metro tunnels. *Proc. Int. Symp. on Geot. Aspects of Underground Constrn. in Soft Ground*, (Eds: Bakker et al.). 151–157. Taylor Francis Group, London.

Nyren, R.J. 1998. *Field measurements above twin tunnels in London Clay*. PhD thesis, Imperial College, University of London.

Thomas, H.S.H. 1977. Measuring structural performance of cast iron tunnel linings in laboratory. *Ground Engng.*, **10**, 5, 29–36.

Wan, M.S.P. 2014. *Field monitoring of ground response to EPBM tunnelling close to existing tunnels in London Clay*. PhD thesis, Imperial College London.

Wan, M.S.P. & Standing, J.R. 2014a. Lessons learnt from installation of field instrumentation to monitor ground response to tunnelling. *Proc. ICE – Geot. Engng.,* **167**, GE5, 491–506.

Wan, M.S.P. & Standing, J.R. 2014b. Measuring pore water pressure by multi-level vibrating wire piezometers. *Proc. ICE – Geot. Engng.,* **167***,* GE6, 547–564.

Yu, J.B.Y. 2014. *Assessing ground interaction effects and potential damage on existing tunnels before and after new excavation works*. PhD thesis, Imperial College London.

Yu J. Standing J.R. Vollum R. Potts D. M. and Burland J.B. 2014. Stress and strain monitoring at Tottenham Court Road Station, London, UK. *Proc. ICE – Structures and Buildings* (http//dx.doi.org/10.1680/stub.14.00012).

Field testing of large diameter piles under lateral loading for offshore wind applications

Essais sur site de pieux de large diamètre soumis à des chargements latéraux pour des applications dans le domaine de l'éolien offshore

B.W. Byrne, R.A. McAdam, H.J. Burd, G.T. Houlsby, C.M. Martin, K. Gavin, P. Doherty, D. Igoe, L. Zdravković, D.M.G. Taborda, D.M. Potts, R.J. Jardine, M. Sideri, F.C. Schroeder, A. Muir Wood, D. Kallehave and J. Skov Gretlund

ABSTRACT Offshore wind power in the UK, and around Europe, has the potential to deliver significant quantities of renewable energy. The foundation is a critical element in the design. The most common foundation design is a single large diameter pile, termed a monopile. Pile diameters of between 5m and 6m are routinely used, with diameters up to 10m or more, being considered for future designs. Questions have been raised as to whether current design methods for lateral loading are relevant to these very large diameter piles. To explore this problem a joint industry project, PISA, co-ordinated by DONG Energy and the Carbon Trust, has been established. The aim of the project is to develop a new design framework for laterally loaded piles based on new theoretical developments, numerical modelling and benchmarked against a suite of large scale field pile tests. The project began in August 2013 and is scheduled to complete during 2015. This paper briefly outlines the project, focusing on the design of the field testing. The testing involves three sizes of pile, from 0.27m in diameter through to 2.0m in diameter. Two sites will be used; a stiff clay site and a dense sand site. Tests will include monotonic loading and cyclic loading. A suite of site investigation will be carried out to aid interpretation of the field tests, and will involve in-situ testing, standard laboratory testing and more advanced laboratory testing.

1 INTRODUCTION

More than 1000 offshore wind turbines have been installed in European waters, and many thousands more are planned to be installed over the next decade. The most common foundation type for these turbines is the monopile, which in recent installations involve diameters of 6 m, with plans to use diameters of 7.5 m (e.g. DONG Energy Gode Wind Offshore Wind Farm) or more, in the future. Monopiles are predominantly subject to large overturning moments, due to lateral wind and wave loads. The method typically adopted for their design is based on the Winkler model, commonly termed the *p-y* approach. The current offshore design guidelines (e.g. DNV 2014; API 2010) use a *p-y* approach that is based on field tests of slender piles, carried out in the 1950s and 1960s, and such methods have been used successfully for oil and gas structures over many decades. However, the measured response of modern offshore wind turbines, designed using these codes, has varied significantly from the predicted response (Kallehave et al. 2012). This suggests that the traditional design methods perhaps do not accurately capture the key mechanisms by which large diameter monopiles interact with the ground.

1.1 Overview of PISA Project

To address these concerns and to develop a new design method for offshore wind turbines, a large joint industry project, PISA (**Pi**le **S**oil **A**nalysis) was established. The project involves three strands of work including (a) the development of a new design methodology (see Byrne et al. 2015), (b) numerical modelling from which the design method is developed (see Zdravkovic et al. 2015) and finally (c) field testing to provide data against which new methods can be assessed and validated. The overall structure of the project is summarised in Figure 1. The numerical modelling work-stream has provided input into the design of the field testing, as well as providing the basis for development of the new design method. The new design method has been developed for a sand soil and a clay soil, both of which are representative of parts of the North Sea where offshore wind farms will be developed. The framework is developed so that it can be easily applied to other soil types, and also to layered soils. The initial focus of the work is for monotonic loading, so that the baseline pile response model is robust, but future phases of work will explore design for cyclic loading. This paper focuses on the design of the proposed field testing phase of work, which is planned for completion during the winter of 2014/2015. The final report for the PISA project will be delivered towards the end of 2015.

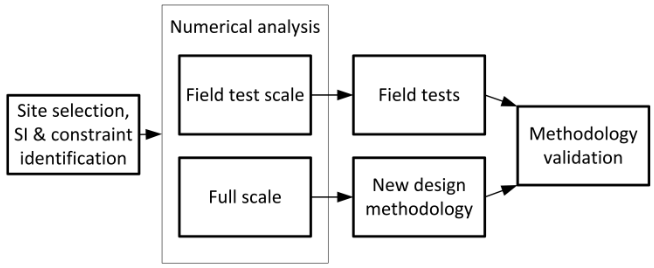


Figure 1. PISA project workflow.

2 TEST SITES

The testing must provide a good representation of pile response in stiff to very stiff over-consolidated ductile Quaternary clay and dense to very dense marine Pleistocene sands. Two on-shore sites, representative of these materials, have been identified for the field testing phase; (a) Cowden, a clay till site in the north-east England, and, (b) Dunkirk, a dense sand site in northern France. These sites represent typical soil conditions found at many North Sea wind farm sites. Both sites have been used for previous pile testing activities and, as a consequence, various field and laboratory soil data are available. This makes them ideal reference materials for the development of the new design methods. Further details of the soil profiles are given in Zdravković et al. (2015).

3 PILE TEST APPROACH

At each site it is envisaged that 14 pile tests will be carried out, each exploring different aspects of the lateral loading problem. During the field tests each test pile will be loaded against a larger reaction pile using a tension based system, as illustrated in Figure 2. This means that it will only be possible to apply one-way loading to the piles, for the cyclic loading tests. The piles will be loaded at a height, *h*, above ground of between 5 - 10m. The heights selected represent normalized load eccentricities, M/HD, that are representative of the wind and wave loading on full scale wind turbine structures, where H is the lateral load and M is the moment in the pile at ground level. For example a value of $M/HD \sim 5$ represents wave loading on an offshore wind turbine, whilst a value of about 15 represents more closely wind loading. Applying the loading in this way ensures that the pile kinematics is correctly simulated, so that the mobilisation of different components of soil resistance is representative. Most other lateral loading field test programmes apply the load at ground level, which in this instance is not appropriate. However, applying the load at such height above the ground, introduces a degree of complexity, and cost, to the pile testing.

3.1 Instrumentation

The piles and areas around the pile will be instrumented to measure the response of the soil and the deflection of the piles. This will be achieved through a combination of instrumentation mounted in the buried pile section and in the above ground pile stick-up. The detailed instrument specifications take into account the physical constraints, such as size and robustness, and technical constraints such as likely displacements, stress ranges, temperature effects, shock loading and g-forces during pile installation.

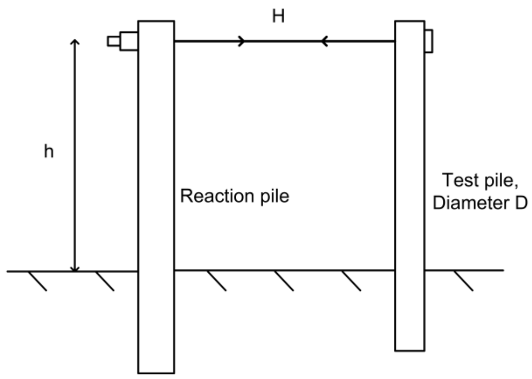


Figure 2. Pile test illustration.

3.1.1 Soil response instrumentation

The two parameters that are measured in the buried pile section are the vertical strain and the inclination of the pile. By measuring the distribution of strain on the active and passive sides of the pile, as illustrated in Figure 3, the depth-wise distribution of bending moment can be calculated. Strain will be predominantly measured using fibre optic cables etched with Bragg Gratings, which are bonded into grooves machined in the pile outer face. In the situation where a cable is damaged during installation, redundancy on the strain measurements is achieved using multipoint retrievable extensometers, mounted within tubes that are welded to the inner face of the pile.

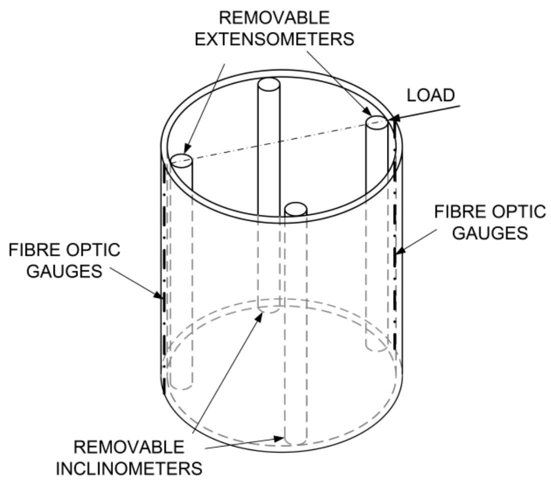


Figure 3. Illustration of soil reaction instrumentation.

The inclination of the pile is measured using retrievable inclinometers mounted in tubes welded to the inner face of the piles, perpendicular to the line of loading. For the calibration of a conventional *p-y* approach the lateral load on the pile would be calculated from the second differential of the distribution of the moment. However, for large diameter piles, the bending moment in the pile occurs due to a combination of lateral loads and vertical shear forces, as described in Section 5. This means that the bending moment distribution (determined from the strain gauges) cannot be related directly to the distribution of the lateral load.

3.1.2 Pile stick-up response instrumentation

Above the ground measurements are made of the pile displacement, inclination and load, as illustrated in Figure 4. Linear variable differential transformers (LVDTs) are used to measure displacements, from which the rotation can be calculated. These will be mounted on independent reference frames, isolated from the ground movements due to the pile. LVDTs placed either side of the pile will allow local changes in pile cross-section to be determined. Bolt-on inclinometers, mounted on the pile stick-up, will provide further validation of the LVDT measurements, offering additional redundancy to the instrumentation system, whilst also allowing horizontal displacement due to translation and rotation to be decoupled. Load cells at the pile head, within the loading system, will allow measurement of the load applied to the pile. It is expected that the loads applied will vary from 10kN for the small diameter piles up to 4000kN for the large diameter piles.

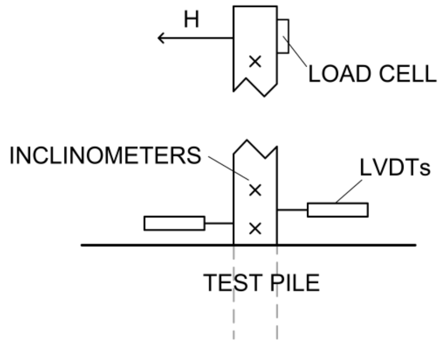


Figure 4. Illustration of stick-up instrumentation.

3.1.3 Pore pressure instrumentation

For a small selection of tests carried out at the clay site, the pore pressures developed in the surrounding soil, as a result of pile installation and loading, will be measured using vibrating wire push-in piezometers. On those instrumented piles, piezometers are located at two radial distances from the pile wall, on both the active and passive sides of the pile, an example is shown in Figure 5. At each radial distance, three piezometers are used to capture data at depths of approximately 0.3L, 0.5L and 0.9L.

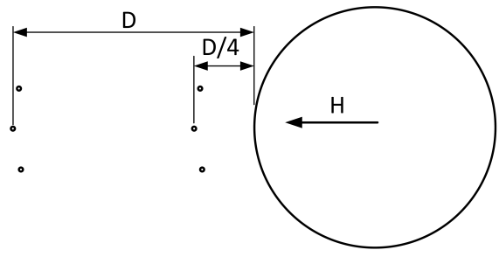


Figure 5. Plan layout of piezometers on the 2.0m diameter pile.

3.2 Site Investigation

Although the two sites have been highly characterised, through previous testing programmes, it has still been necessary to collect new data for each site. A programme of in-situ testing has been carried out including CPT, Pressuremeter, SDMT and Magcone testing. The testing is broadly aligned with previous measurements taken at the sites. In addition soil sampling has been carried out with additional laboratory testing planned to assist with the further development of the numerical modelling, particularly for the cyclic loading analysis. Robust information on the site characteristics is an important input into the new design methods.

4 TEST PARAMETER SPACE

The field tests cover a range of pile geometries, including relatively long and short piles. The displacement of these piles is anticipated to be due to a combination of bending and rigid body rotation. Based on this assumption, two metrics for the target threshold on pile response have been chosen; a ground level lateral displacement of 0.1*D* or a ground level rotation of 2 degrees.

For each test in which the piles are monotonically loaded, the piles would ideally pass both target thresholds, developing high strains in the pile, which can provide a high resolution approximation of the bending moment distribution and the resulting distribution of loads. However, to ensure that the response of the pile remains linear elastic, the stresses in the pile should not exceed the yield stress. The geometry of the piles must therefore be selected to maximize the pile strains up to the desired threshold load. Figure 6 illustrates the design problem; a pile that is inappropriately sized (such as Pile A) will yield before the target rotation and displacement thresholds are reached. Conversely, Pile B is able to reach these thresholds without yielding.

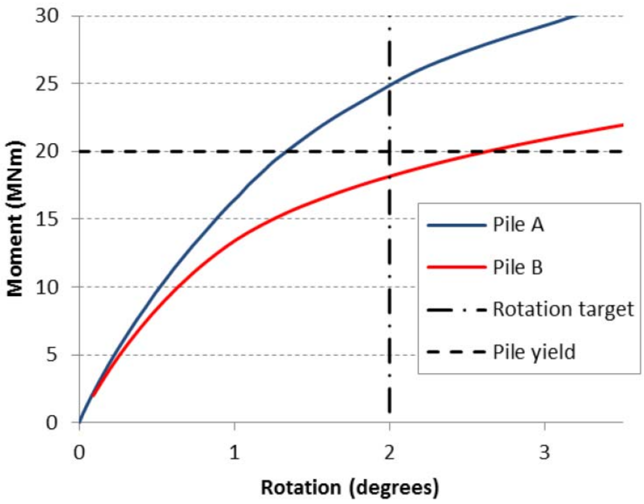


Figure 6. Example plot of pile displacement and failure.

Piles of eight different geometries have been chosen, as shown in Table 1. These piles are scaled representative of the geometry of current and future offshore wind turbine foundations. Due to the stiffer response of the Dunkirk soil a greater load is generally required to achieve the target rotation or displacement. Where there is a range of geometry shown in Table 1, the piles in Dunkirk are those of greatest thickness or shorter length to resist these increased loads. Figure 7 and 8 show dimensionless pile geometries for the test piles at Cowden and Dunkirk, compared against geometries considered to be representative of monopiles and jacket piles. Also plotted is a line that represents the boundary between pile yield and soil failure. This line is determined for the pile geometries, loading conditions and soil conditions that are relevant to the pile tests.

Table 1. Parameter space of field tests.

Geometry	Diameter	L (m)	L/D	t (mm)	D/t
1	0.273	1.4	5.25	7	39
2	0.273	2.2	8	7	39
3	0.273	2.7	10	7	39
4	0.762	2.3	3	10	76
5	0.762	4	5.25	15 – 19	40 - 51
6	0.762	4	5.25	11– 14	54 - 69
7	0.762	6.1 – 7.6	8 - 10	25	30
8	2.0	10.5	5.25	25 - 38	53 - 80

4.1 Test types

The testing will consist mostly of monotonic loading events. This is essential for definition of the baseline response of the pile, and for comparison against the predictions made by the numerical analyses. The monotonic tests will incorporate unload-reload events so that the evolution of stiffness and hysteresis can be identified. For example Figure 9 shows a schematic of a typical monotonic test. A small number of tests will be devoted to cyclic loading, such as the oneway loading events shown in Figure 9. This information will provide the basis for developing methods that can predict the accumulation of rotation (or displacement) and the stiffening or degradation of the response. In addition, such events provide very important detail on the hysteresis that might be expected. This is needed for developing design guidance on damping from the foundation, which will mainly be derived from the hysteretic response. The assessment of damping is critical for determining the applied loads due to turbine operation, wave and wind loading and so consequently for fatigue design.

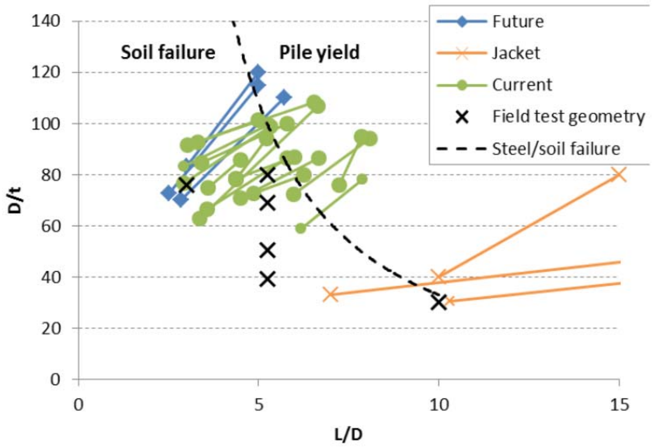


Figure 7. Geometry space in glacial till clay at Cowden.

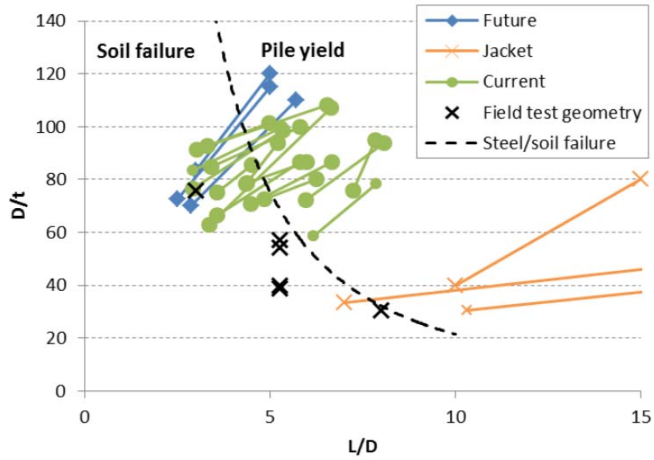


Figure 8. Geometry space in Flandrian sand at Dunkirk.

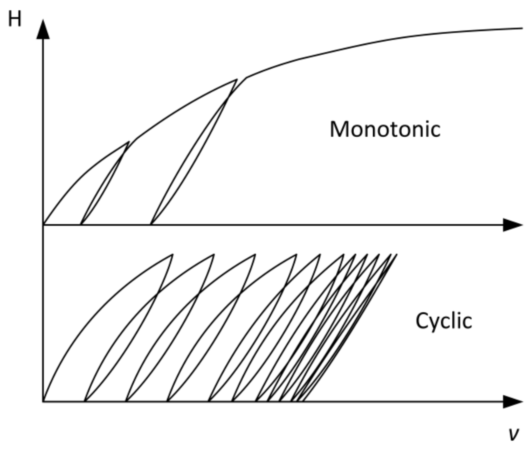


Figure 9. Illustration of test types.

5 FIELD TEST DATA ANALYSIS

The field tests are designed to provide a high quality data set for benchmarking new design methods for laterally loaded piles. Pile-head load displacement data will be an important indicator of the accuracy of the numerical modelling that has been carried out (Zdravković et al. 2015). Based on the modelling Byrne et al. (2015) describe a new design method that builds on the existing *p-y* approach, but which allows for additional components of the soil resistance. These additional components are shown in Figure 10. The importance of each component depends on the pile geometry, and pile kinematics under loading. For longer small diameter piles the inferred *p-y* relationship will be a good approximation to the pile response. However, for many of the tests it will be necessary to carry out additional numerical simulations, to properly extract the contribution from the different soil reactions. The instrumentation will allow detailed analysis of bending strains down the pile, of the pile deflected shape, as well as any pore pressures that develop in the soil around the pile. There is a degree of instrumentation redundancy to ensure the success of the programme. A small number of tests will explore cyclic loading. Instrumentation allows the cycle by cycle behaviour to be resolved, as well as any accumulation or stiffening.

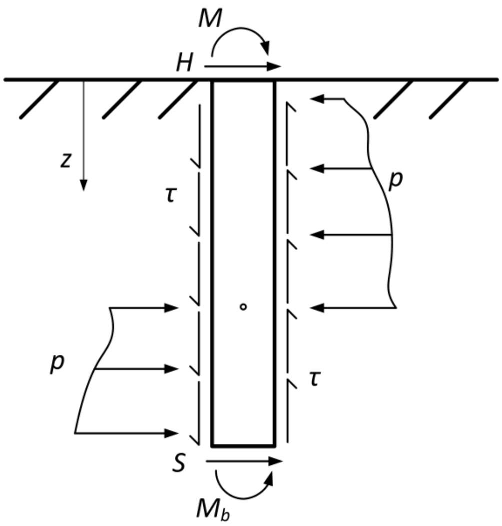


Figure 10. Diagrammatic indication of the soil reaction components applied to a monopile (based on the modelling assumptions outlined in Byrne et al. 2015).

6 CONCLUSIONS

This paper describes a field testing programme to explore the monotonic and cyclic lateral load response of piles for offshore wind applications. A large number of highly instrumented and appropriately loaded piles will be tested at a stiff clay site and a dense sand site. The resulting data will be used to benchmark numerical modelling that has been carried out (Zdravković et al. 2015), and the new design methods that have been developed (Byrne et al. 2015). The initial focus of the work is for monotonic loading, but data will be collected from cyclic tests, to aid development of cyclic load design guidance.

ACKNOWLEDGEMENT

The Authors acknowledge the funding by the project partners including the Carbon Trust through the Offshore Wind Accelerator, DONG Energy, Iberdrola, RWE, SSE, Statoil, Statkraft, Vattenfall, Alstom and EDF.

REFERENCES

API. 2010. *RP 2A-WSD - Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms*. Washington: American Petroleum Institute.

Byrne, B.W., McAdam, R., Burd, H.J., Houlsby, G.T., Martin, C.M., Zdravković, L., Taborda, D.M.G., Potts, D.M., Jardine, R.J., Sideri, M., Schroeder, F.C., Gavin, K., Doherty, P., Igoe, D., Muir Wood, A., Kallehave, D. & Skov Gretlund, J. 2015. New design methods for large diameter piles under lateral loading for offshore wind applications. *Proc 3rd International Symposium on Frontiers in Offshore Geotechnics (ISFOG 2015)*. Oslo, Norway

DNV. 2014. *DNV-OS-J101 - Design of Offshore Wind Turbine Structures*. Oslo: Det Norske Veritas.

Kallehave, D., Leblanc, C. & Liingaard, M.A. 2012 *Modification of the API p-y formulation of initial stiffness of sand. Proc. 7th International Conference on Offshore Site Investigation and Geotechnics,* 465-472

Zdravković, L., Taborda, D.M.G., Potts, D.M., Jardine, R.J., Sideri, M., Schroeder, F.C., Byrne, B.W., McAdam, R., Burd, H.J., Houlsby, G.T., Martin, C.M., Gavin, K., Doherty, P., Igoe, D., Muir Wood, A., Kallehave, D. & Skov Gretlund, J. 2015. Numerical modelling of large diameter piles under lateral loading for offshore wind applications. *Proc 3rd International Symposium on Frontiers in Offshore Geotechnics (ISFOG 2015)*. Oslo, Norway.

ΠΑΡΟΥΣΙΑΣΗ ΔΙΔΑΚΤΟΡΙΚΩΝ ΔΙΑΤΡΙΒΩΝ ΣΤΗΝ ΓΕΩΤΕΧΝΙΚΗ ΜΗΧΑΝΙΚΗ

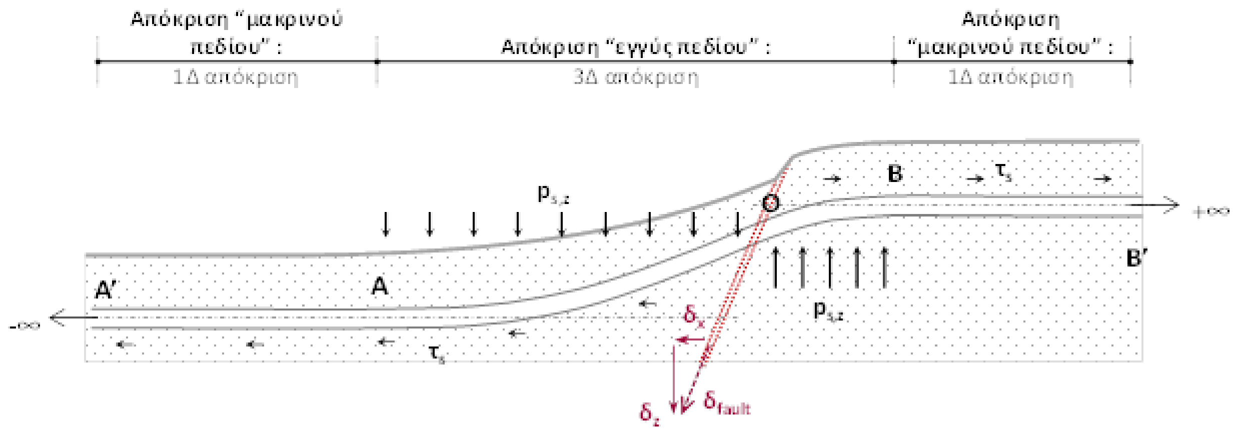
Πειραματική και Αριθμητική Προσομοίωση Αγωγών έναντι Μεγάλων Εδαφικών Μετακινήσεων: Τεκτονική Διάρρηξη, Κατολίσθηση

Άγγελος Τσάτσης, Διδάκτωρ Ε.Μ.Π

Η παρούσα Διδακτορική Διατριβή περιλαμβάνει δύο κύριες ενότητες. Η πρώτη ενότητα είναι αφιερωμένη στην απόκριση υπογείων αγωγών υποβαλλόμενων σε τεκτονική διάρρηξη κατακόρυφης βύθισης (κανονικά και ανάστροφα ρήγματα). Στόχος μας είναι η πλήρης προσομοίωση της διάδοσης της διάρρηξης από το βραχώδες υπόβαθρο έως την επιφάνεια του εδάφους και η ταυτόχρονη μελέτη της δομητικής απόκρισης του αγωγού. Πλέον της ανελαστικής ανάλυσης του εδάφους και των συνθηκών επαφής εδάφους-αγωγού, ιδιαίτερη έμφαση δίδεται στην ορθή ανάλυση της εντόνως μή-γραμμικής απόκρισης του μεταλλικού κελύφους. Η δεύτερη ενότητα αναφέρεται στην απόκριση υπογείων αγωγών υποβαλλόμενων σε μεγάλες εδαφικές μετακινήσεις λόγω ενεργοποίησης εδαφικής κατολίσθησης. Καί για τις δύο (2) φορτίσεις καταρτήθηκε κατάλληλη αριθμητική μεθοδολογία η οποία εν συνεχεία βαθμονομήθηκε και επαληθεύτηκε έναντι πειραμάτων της βιβλιογραφίας και πειραμάτων μικρής κλίμακας που διεξήχθησαν στο Εργαστήριο Εδαφομηχανικής του Ε.Μ.Π.

<u>Μέρος Α' : Αγωγός υποβαλλόμενος σε τεκτονική διάρρηξη</u>

Ως γνωστόν οι τοπικές εδαφικές συνθήκες επηρεάζουν την διαδρομή (rupture path) και την εμφάνιση (outcrop) του σεισμικού ρήγματος στην ελεύθερη επιφάνεια του εδάφους. Εν προκειμένω, (όπως σχηματικά παρουσιάζεται στο Σχ. 1) η σχεδόν σημειακή διαφορική μετακίνηση (δ_{fault}) στο επίπεδο του βράχου, καθώς μεταδίδεται προς τα άνωθεν, διαχέεται εντός του ενδόσιμου εδάφους σχηματίζοντας έναν ηπιότερο αναβαθμό. Αυτό ακριβώς το κινηματικό πεδίο καλείται να παραλάβει ο μεταλλικός αγωγός. Ως αναμένετο, εντός της ζώνης διαρρήξεως (εγγύς πεδίου περιοχή) η απόκριση τόσο του εδάφους όσο και του αγωγού είναι πρακτικώς τρισδιάστατη, ενώ πέραν ενός μήκους επιρροής (μακρινό πεδίο) ο αγωγός τείνει να 'συμμορφωθεί' με την κατακόρυφη μετατόπιση του εδάφους και η απόκρισή του εκφυλίζεται σε αποκλειστικώς αξονική (μονοδιάστατη). Ο άνω διαχωρισμός σε 'εγγύς' και 'μακρινό' πεδίο διατηρήθηκε και στην προτεινόμενη αριθμητική μεθοδολογία. Εν προκειμένω, η 'εγγύς πεδίου' προσομοίωση περιλαμβάνει 3-Δ κάνναβο Π.Σ. όπου το έδαφος προσομοιώνεται με στοιχεία συνεχούς μέσου και ο αγωγός με στοιχεία κελύφους. Η μη-γραμμική συμπεριφορά του χάλυβα περιγράφεται από ένα καταστατικό προσομοίωμα von Mises, ενώ για την ρεαλιστική απεικόνιση της εδαφικής συμπεριφοράς (διάδοση της διάρρηξης, συγκέντρωση παραμορφώσεων στο επίπεδο αστοχίας, πτώση της αντοχής για διαστολικά εδάφη κλπ.) υιοθετείται ένα ελαστοπλαστικό καταστατικό προσομοίωμα με κριτήριο αστοχίας Mohr-Coulomb και συμπεριφορά χαλάρωσης (Anastasopoulos et al. 2007). Πέραν της 3-Δ κεντρικής περιοχής η προσομοίωση περιλαμβάνει στοιχεία δοκού για τον αγωγό και κατάλληλα αξονικά ελατήρια για το έδαφος.

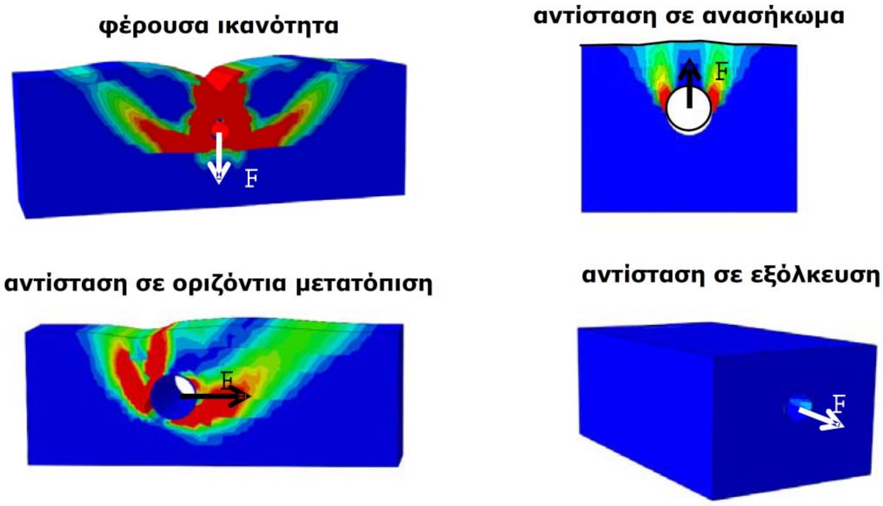


Σχήμα 1. Ποιοτική απεικόνιση της απόκρισης υπογείου απειρομήκους αγωγού υποβαλλόμενου σε κανονική διάρρηξη

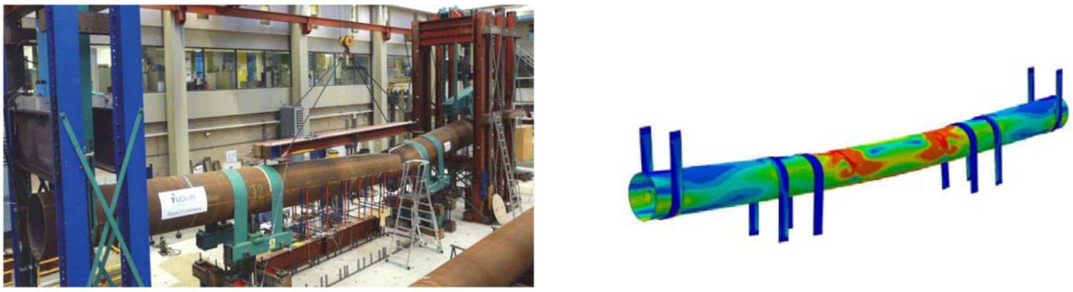
Για την τεκμηρίωση της προτεινόμενης αριθμητικής μεθοδολογίας αξιοποιήθηκαν : (α) πειράματα (μικρής και μεγάλης κλίμακας) μονοαξονικής μετατόπισης αγωγού με στόχο την επαλήθευση/βαθμονόμηση του εδαφικού καταστατικού προσομοιώματος (Σχ. 2α), (β) πειράματα καθαρής κάμψης μεταλλικών αγωγών (Σχ. 2β) και (γ) πειράματα 1-g αλληλεπίδρασης αγωγού-ρήγματος.

Η τελευταία κατηγορία πειραμάτων έλαβε χώρα στο Εργαστήριο Εδαφομηχανικής του Ε.Μ.Π. Σε σύνολο 26 πειραμάτων εξετάστηκε τόσο η διάδοση κανονικής και ανάστροφης διάρρηξης μέσω αμμώδους σχηματισμού όσο και η απόκριση αγωγών διαφόρων γεωμετρικών χαρακτηριστικών. Ένα ενδεικτικό παράδειγμα το οποίο αφορά σε χαλύβδινο αγωγό διαμέτρου D=35 mm και πάχους t=0.5 mm υποβαλλόμενο σε ανάστροφη τεκτονική διάρρηξη αποτυπώνεται στο Σχ. 3. Εμφανώς η αριθμητική μεθοδολογία περιγράφει ικανοποιητικά τόσο την εδαφική απόκριση όσο την δομητική αστοχία του αγωγού.

Για την επαλήθευση της μεθόδου προσομοίωσης της συμπεριφοράς «μακρινού πεδίου», αξιοποιήθηκαν πειράματα εξόλκευσης αγωγού μεγάλης κλίμακας. Έμφαση δόθηκε στην επίδραση της διαστολικότητας του εδάφους, λόγω της οποίας αυξάνεται η αξονική εδαφική αντίδραση. Για την ποσοτικοποίηση της επίδρασης αυτής αναπτύχθηκε πρωτότυπη απλοποιημένη μεθοδολογία που λαμβάνει υπόψη την αύξηση της ορθής τάσης στην διεπιφάνεια αγωγού-εδάφους εξαιτίας της εμποδιζόμενης τάσης για διόγκωση.



(α)



(β)

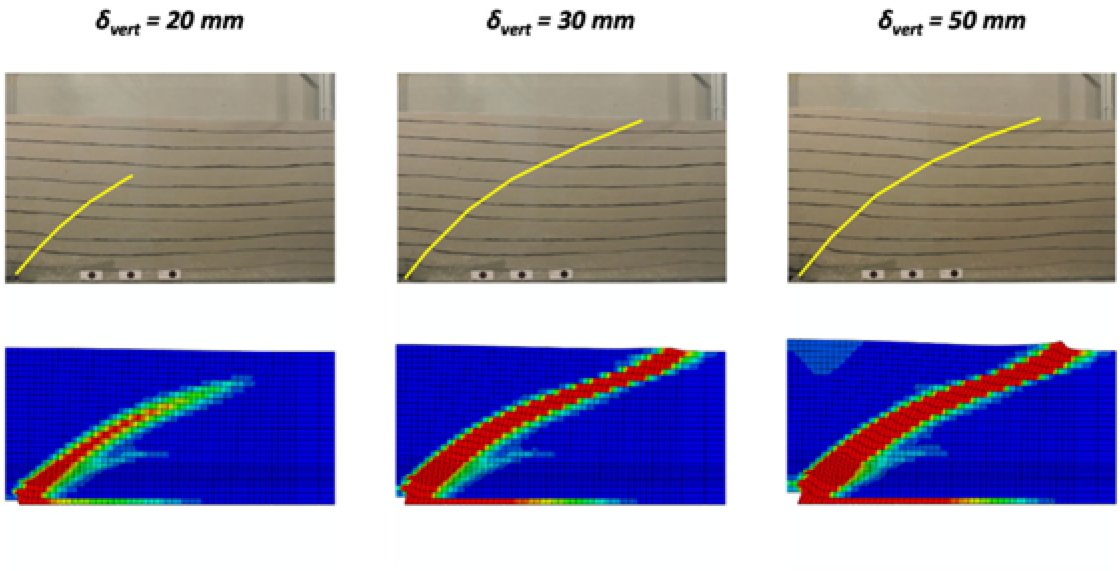
Σχήμα 2. Αρχικώς η μέθοδος προσομοίωσης με πεπερασμένα στοιχεία επαληθεύεται έναντι πειραμάτων μονοαξονικής μετατόπισης του αγωγού μέσα στο έδαφος αλλά και έναντι πειραμάτων καμπτικής καταπόνησης του αγωγού.

Εν συνεχεία, έχοντας βαθμονομήσει και επαληθεύσει την αριθμητική μεθοδολογία, μελετήθηκε παραμετρικώς η δομητική συμπεριφορά υπογείων χαλύβδινων αγωγών απείρου μήκους υποβαλλόμενων σε κανονική και ανάστροφη διάρρηξη. Επιλέχθηκαν γεωμετρίες αντιπροσωπευτικές αγωγών μεταφοράς υδρογονανθράκων (με σχετικώς μεγάλες διαμέτρους από *D*=28″ έως *D*=48″ και λόγο διαμέτρου προς πάχος τοιχώματος D/t≈70), και μελετήθηκε η συμπεριφορά τους μέχρι την αστοχία, εξετάζοντας την επίδραση των εδαφικών παραμέτρων (αντοχή, διαστολικότητα, μέτρο ελαστικότητας) και του βάθους εγκιβωτισμού. Τα αποτελέσματα ομαδοποιήθηκαν και ενδιαφέροντα συμπεράσματα εξήχθησαν σχετικά με την επιρροή της εσωτερικής πίεσης και της αξονικής δρώσας δύναμης στην παραμορφωσιμότητα και ευπάθεια του αγωγού.

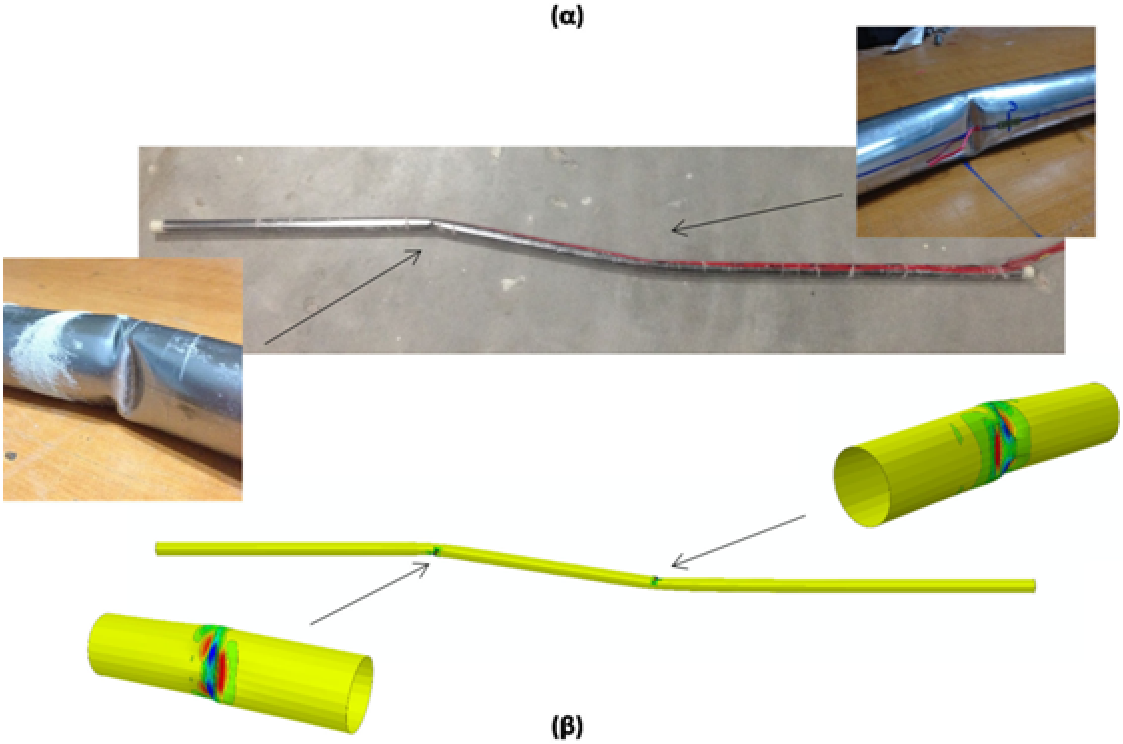
Η παρούσα διατριβή επιχειρεί και μία σύντομη αξιολόγηση της αξιοπιστίας των ευρέως χρησιμοποιούμενων ελατηριωτών προσομοιωμάτων. Ως εκ τούτου, επιλέχθηκαν δύο τυπικές διατάξεις υπογείων αγωγών οι οποίες υπεβλήθησαν σε κανονική και ανάστροφη διάρρηξη. Τα επιλεχθέντα συστήματα επιλύθηκαν: (α) με τη χρήση της εμπεριστατωμένης αριθμητικής μεθοδολογίας και (β) με χρήση απλοποιημένου προσομοιώματος δοκού επί ελατηριωτού εδάφους. Για την δεύτερη κατηγορία υιοθετήθηκαν και αξιολογήθηκαν δύο εναλλακτικές προσεγγίσεις. Στην πρώτη τα εδαφικά ελατήρια έχουν προκύψει από αναλύσεις πεπερασμένων στοιχείων, ενώ στην δεύτερη τα εδαφικά ελατήρια υπακούν στις ημι-εμπειρικές σχέσεις των κανονιστικών διατάξεων (ALA 2001). Η απ’ ευθείας αυτή σύγκριση αναδεικνύει περιπτώσεις σημαντικής απόκλισης. Ενδεικτικά αναφέρεται ότι στις περιπτώσεις κανονικής διάρρηξης τα ελατηριωτά προσομοιώματα τείνουν να υπερεκτιμούν την εδαφική αντίσταση (καθώς αγνοούν την μείωση της αντοχής του εδάφους λόγω των συνθηκών ενεργητικής αστοχίας), με αποτέλεσμα τη σημαντική υπερεκτίμηση της καμπτικής παραμόρφωσης του αγωγού. Επιπλέον, σε περιπτώσεις σημαντικής εσωτερικής πίεσης, η προσομοίωση του αγωγού με στοιχεία δοκού υποεκτίμα σημαντικά τις αναπτυσσόμενες παραμορφώσεις, καθώς αγνοεί την όχι αμελητέα παραμόρφωση στο επίπεδο της διατομής και τα συνεπαγόμενα φαινόμενα 2^{ας} τάξης που οδηγούν σε μείωση της δυσκαμψίας του αγωγού.

<u>Μέρος Β΄: Αλληλεπίδραση Αγωγού-Κατολίσθησης</u>

Στην δεύτερη ενότητα της Διδακτορικής διατριβής ερευνήθηκε η απόκριση απειρομήκους υπογείου αγωγού υποβαλλόμενου σε μεγάλες εδαφικές μετακινήσεις προκαλούμενων από εκδήλωση περιστροφικής κατολίσθησης. Μια από τις σημαντικότερες προκλήσεις στην προσομοίωση του φαινομένου απορρέει από την αναντιστοιχία των διαστάσεων μεταξύ αγωγού και κατολίσθησης. Αφενός, η λεπτομερής προσομοίωση του αγωγού και των πιθανών φαινομένων τοπικής αστάθειας (π.χ. τοπικός λυγισμός, οβαλοποίηση) απαιτεί την χρήση πεπερασμένων στοιχείων πολύ μικρών διαστάσεων (της τάξεως λίγων εκατοστών), αφετέρου, η προσομοίωση κατολισθητικών φαινομένων απαιτεί κατά κανόνα προσομοιώσεις μεγάλων διαστάσεων. Ο συγκερασμός των δύο απαιτήσεων οδηγεί σε γιγαντιαία δύσχρηστα και εξαιρετικά απαιτητικά προσομοιώματα. Εναλλακτικά, προτείνεται και υιοθετείται μια μεθοδολογία δύο βημάτων. Αρχικώς αναλύεται η εξέλιξη της κατολίσθησης στο ελεύθερο πεδίο (δηλ. αγνοώντας την ύπαρξη του αγωγού). Από την ανάλυση αυτή εξάγεται το πεδίο των μετακινήσεων, το οποίο στο δεύτερο βήμα χρησιμοποιείται ως συνοριακή συνθήκη στον πυθμένα και στα πλευρικά σύνορα ενός τοπικού προσομοιώματος που περιλαμβάνει τον αγωγό και ένα εδαφικό πρίσμα περί αυτού.

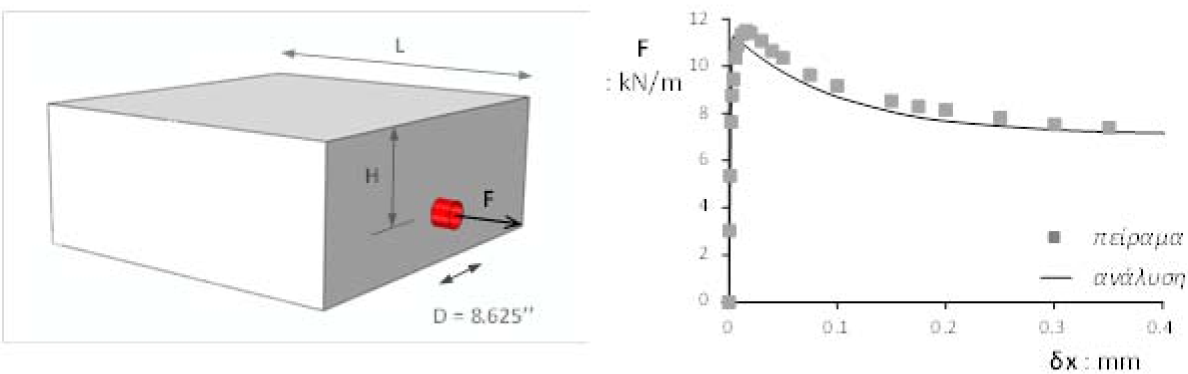


(α)

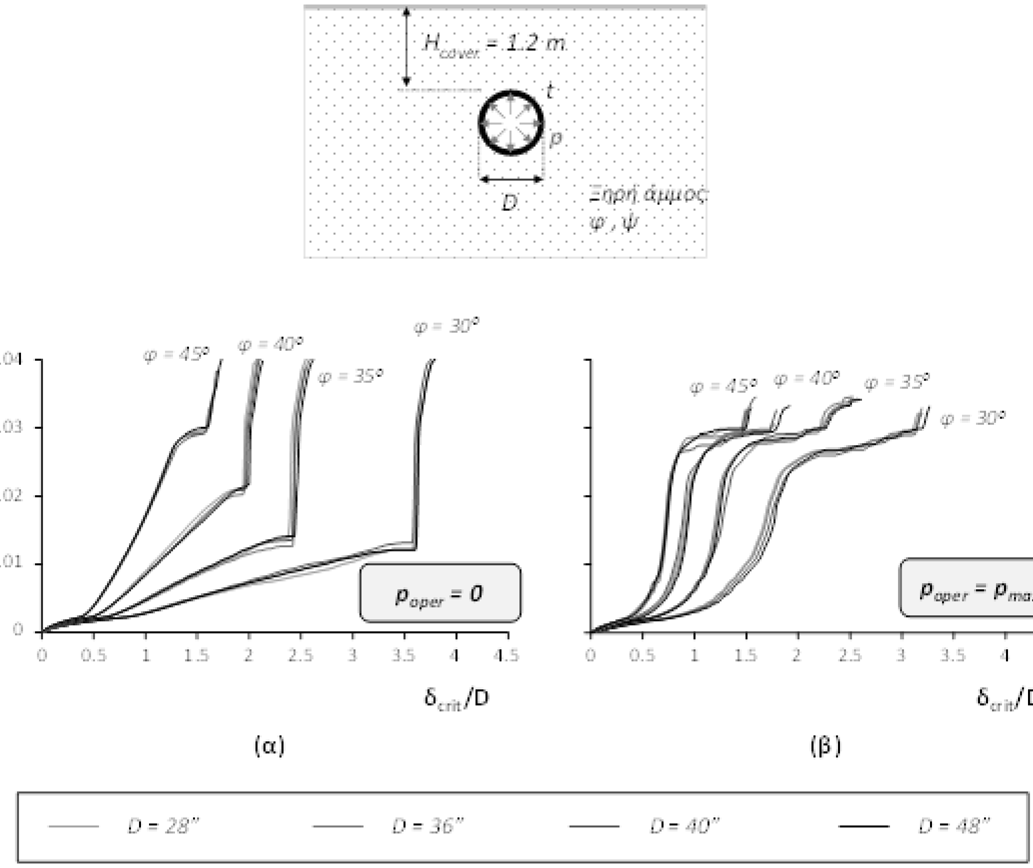


(β)

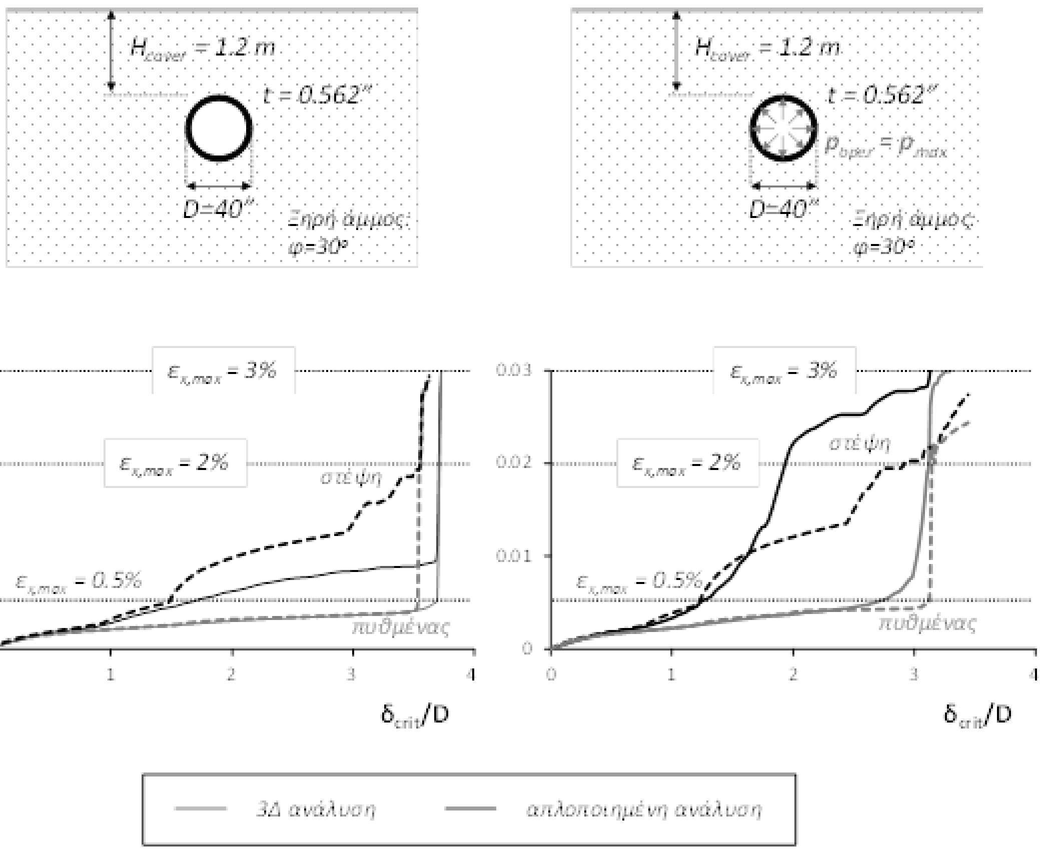
Σχήμα 3. Σύγκριση αριθμητικών και πειραματικών αποτελεσμάτων για την περίπτωση αγωγού υποβαλλόμενου σε ανάστροφη διάρρηξη: (α) διάδοση της διάρρηξης και (β) παραμόρφωση του αγωγού.



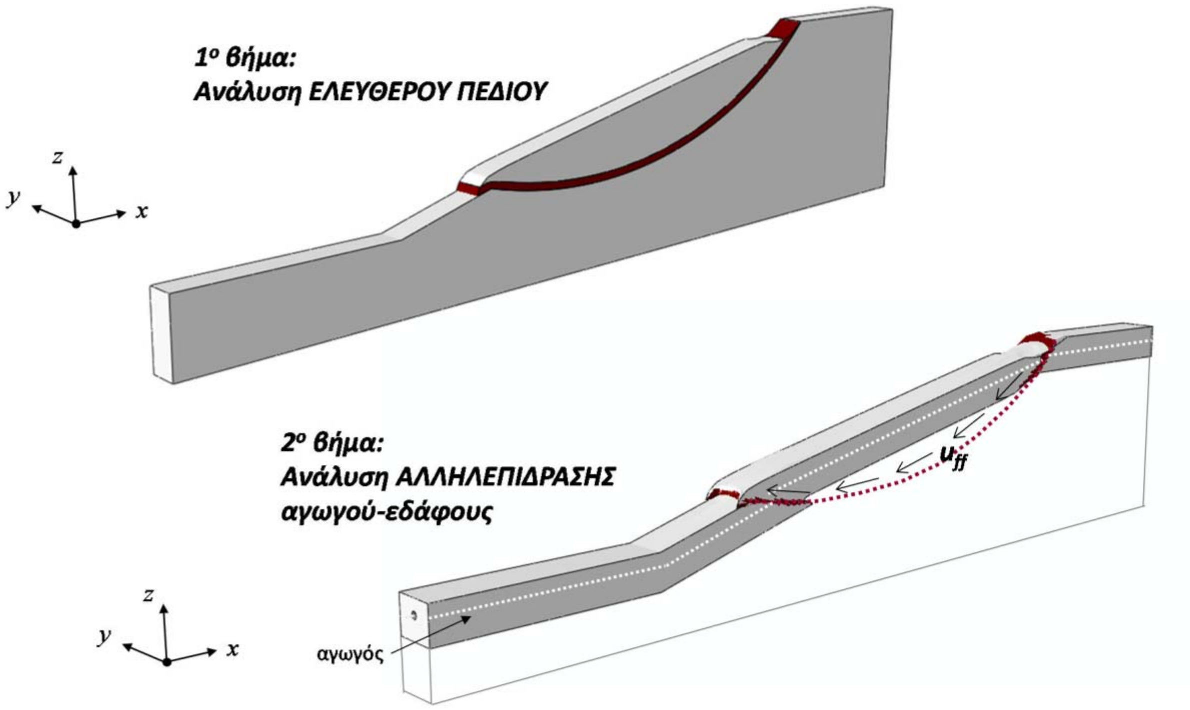
Σχήμα 4. Εξόλκευση αγωγού σε διαστολικό έδαφος: Σύγκριση αριθμητικών και πειραματικών αποτελεσμάτων



Σχήμα 5. Απόκριση υπογείων αγωγών διαμέτρου D και πάχους t ($D/t \approx 70$) εγκιβωτισμένων σε αμμώδη εδάφη γωνίας τριβής φ υποβαλλόμενων σε κανονική διάρρηξη, θεωρώντας εσωτερική πίεση λειτουργίας (α) $p_{oper}=0$ και (β) $p_{oper}=9$ MPa: εξέλιξη της μέγιστης εφελκυστικής παραμόρφωσης με την αύξηση της κανονικοποιημένης μετατόπισης της διάρρηξης.



Σχήμα 6. Σύγκριση 3Δ ανάλυσης Π.Σ. και απλοποιημένου ελατηριωτού προσομοιώματος: εξέλιξη της μέγιστης εφελκυστικής παραμόρφωσης με την αύξηση της κανονικοποιημένης μετατόπισης της διάρρηξης θεωρώντας εσωτερική πίεση λειτουργίας $p_{oper}=0$ και $p_{oper}=9$ MPa.



Σχήμα 7. Μεθοδολογία δύο βημάτων για την ανάλυση της συμπεριφοράς υπογείου αγωγού υποβαλλόμενου σε μεγάλες εδαφικές μετακινήσεις λόγω κατολίσθησης.

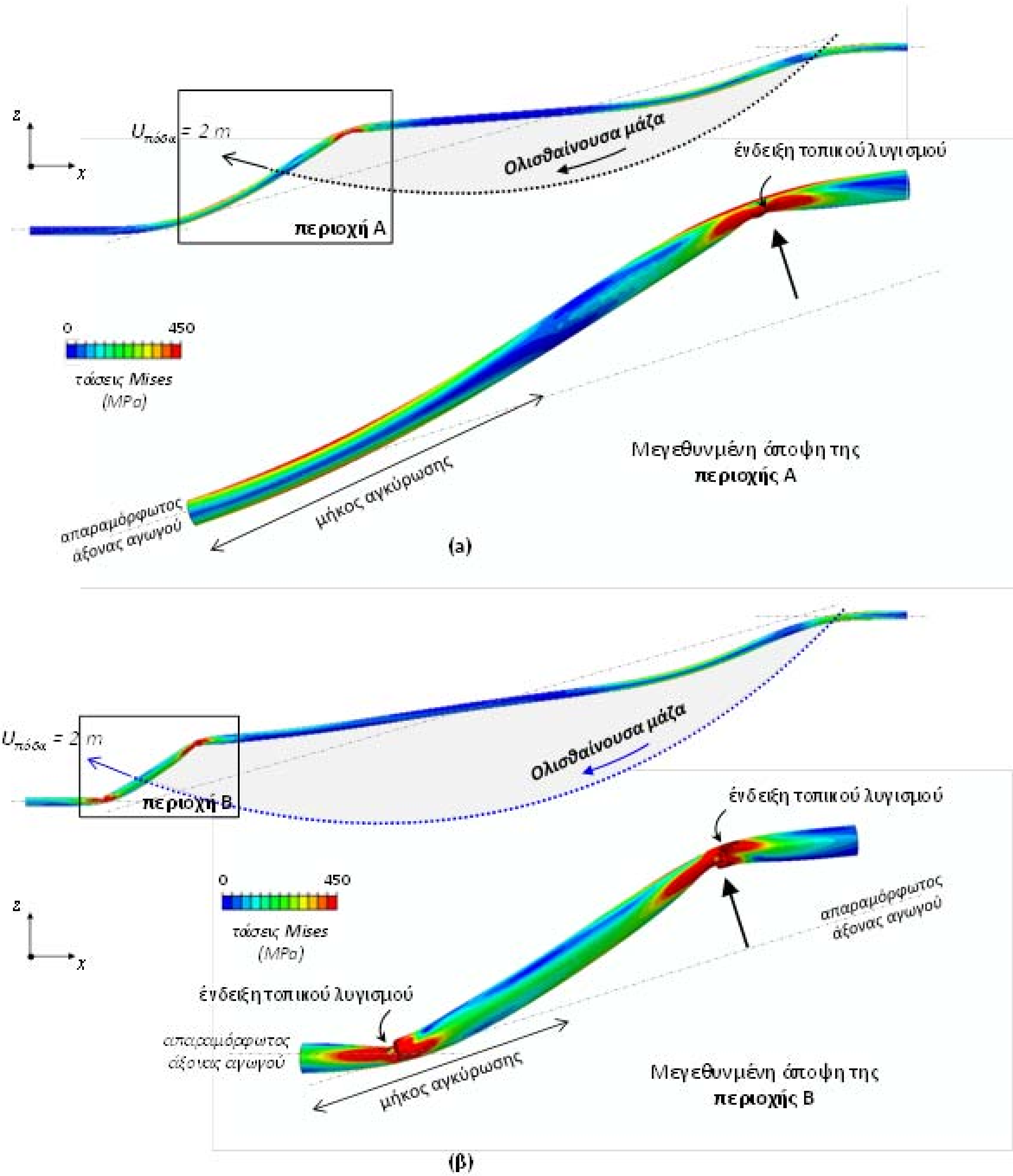
Με την χρήση της ως άνω μεθοδολογίας μελετήθηκε αριθμητικά η απόκριση χαλύβδινου αγωγού διαμέτρου *D*=36″ και πάχους *t*=0.5″ εγκιβωτισμένου σε βάθος *H*=1.5 m για δύο γεωμετρίες κατολίσθησης : (α) ο αγωγός διασχίζει κάθετα το πρανές και επομένως είναι παράλληλος στην κίνηση της κατολισθαίνουσας μάζας και (β) ο αγωγός είναι παράλληλος στην στέψη του πρανούς και η εδαφική ολίσθηση λαμβάνει χώρα κάθετα στον άξονά του. Και για στις δύο περιπτώσεις διερευνήθηκαν συστηματικά οι πλέον πιθανοί μηχανισμοί αστοχίας και εξήχθησαν πολύτιμα συμπεράσματα για τον ρόλο της εσωτερικής πίεσης στην ευπάθεια των αγωγών.

Η διατριβή υποστηρίχθηκε την 5η Μαΐου 2017 στο Εθνικό Μετσόβιο Πολυτεχνείο. Η τριμελής επιτροπή αποτελείτο από τους:

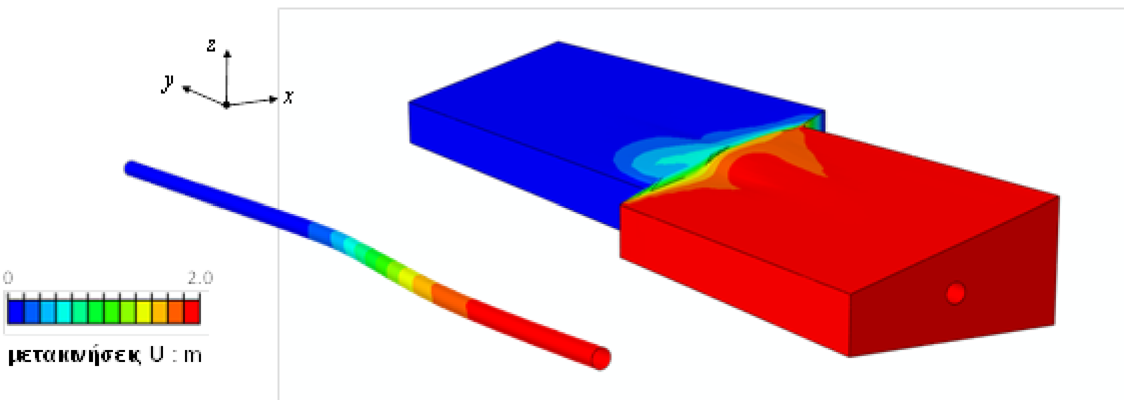
Γ. Γκαζέτα, καθηγητή Ε.Μ.Π.
Π. Ντακούλα, καθηγητή Πανεπιστημίου Θεσσαλίας
Ν. Γερόλυμο, Αναπληρωτή Καθηγητή Ε.Μ.Π.

Επιλέον αυτών, η επταμελής εξεταστική επιτροπή αποτελείτο από τους:

Σ. Καραμάνο, καθηγητή Πανεπιστημίου Θεσσαλίας
Ι. Αναστασόπουλο, καθηγητή ETH Zurich
Χ. Γαντέ, καθηγητή Ε.Μ.Π.
Β. Γεωργιάννου, Αναπληρώτρια Καθηγήτρια Ε.Μ.Π.



Σχήμα 8. Απόκριση αγωγού σε δύο σενάρια κατολίσθησης: (α) σχετικώς ρηχή κατολίσθηση και (β) βαθιά κατολίσθηση που αλληλεπιδρά με το κάτω καμπύλο στοιχείο συναρμογής: στιγμιότυπο παραμορφωμένου καννάβου με ισοϋψείς τάσεων για μετατόπιση εδάφους U=2 m.



Σχήμα 9. Υπόγειος αγωγός υποβαλλόμενος σε κατολίσθηση κάθετη στον άξονα του: στιγμιότυπο παραμορφωμένου καννάβου με ισοϋψείς μετακινήσεων για μετατόπιση εδάφους U=2 m.

ΝΕΑ ΑΠΟ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

ΔΗΜΟΚΡΙΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΡΑΚΗΣ

Φοιτητικός διαγωνισμός οπλισμένου εδάφους στο Δημοκρίτειο Πανεπιστήμιο Θράκης με συμμετοχή φοιτητών από το εξωτερικό

Φοιτητικός διαγωνισμός οπλισμένου εδάφους πραγματοποιήθηκε το Σάββατο 6 Μαΐου 2017, στις εγκαταστάσεις του *Εργαστηρίου Εδαφομηχανικής και Θεμελιώσεων* του *Τμήματος Πολιτικών Μηχανικών* του *Δημοκρίτειου Πανεπιστημίου Θράκης* (ΔΠΘ). Ο διαγωνισμός διοργανώθηκε από την Τοπική Κοινότητα Ξάνθης (LC Xanthi) του International Association of Civil Engineering Students[1] (IACES), στα πλαίσια διεθνούς συνεδρίου (Mid-Term Meeting) του IACES. Το εν λόγω συνέδριο έλαβε χώρα στα νέα κτήρια του Τμήματος Πολιτικών Μηχανικών του ΔΠΘ την περίοδο 2 - 8 Μαΐου 2017. Στο διαγωνισμό, του οποίου την οργάνωση είχαν αναλάβει οι φοιτητές του ΔΠΘ, συμμετείχαν φοιτητές - εκπρόσωποι τοπικών κοινοτήτων του IACES από οχτώ χώρες (Πορτογαλία, Σερβία, Αίγυπτο, Γερμανία, Τουρκία, Αλγερία, Ρουμανία, Ολλανδία).

Ο διαγωνισμός αφορούσε στην κατασκευή "δοκιμίων" οπλισμένου εδάφους με τη χρήση γεωϋφασμάτων και γεωπλεγμάτων και στη συνέχεια, φόρτισή τους έως την αστοχία. Πιο αναλυτικά, διαγωνίσθηκαν εικοσιπέντε φοιτητές χωρισμένοι σε πέντε ομάδες. Οι ομάδες κλήθηκαν ταυτόχρονα, να διαστρώσουν χονδρόκοκκο εδαφικό υλικό εντός ξύλινων κιβωτίων (διαστάσεων 55 cm × 67 cm × 55 cm), τοποθετώντας ενδιάμεσα (κατά την κρίση τους) διαθέσιμα γεωυφάσματα ή/και γεωπλέγματα διαφόρων εφελκυστικών αντοχών και προβαίνοντας σε συμπύκνωση κατά το δοκούν. Μετά την ολοκλήρωση της διάστρωσης το κιβώτιο αφαιρούνταν (μέσω απελευθέρωσης αφαιρούμενων μεντεσέδων) και ακολουθούσε η φόρτιση του δοκιμίου με τη χρήση βαρών. Για τον καθορισμό της νικήτριας ομάδας ελήφθησαν υπόψη η οικονομία στη χρήση υλικού ενίσχυσης, ο χρόνος ολοκλήρωσης διάστρωσης - συμπύκνωσης και το βάρος φόρτισης έως την αστοχία. Παρόντες και επιβλέποντες τον διαγωνισμό ήταν ο Διευθυντής του Εργαστηρίου, Αναπληρωτής Καθηγητής κ. Μάρκου και ο Επίκουρος Καθηγητής κ. Ζευγώλης (ο οποίος και είχε προτείνει στους φοιτητές τη διοργάνωση του εν λόγω διαγωνισμού). Τα υλικά του διαγωνισμού (γεωσυνθετικά υλικά, κιβώτια, κλπ.) ήταν ευγενική χορηγία της εταιρείας Thrace NG (του Ομίλου Πλαστικά Θράκης). Στα πλαίσια του ιδίου συνεδρίου του IACES, είχε προηγηθεί διάλεξη από τον κ. Ζευγώλη, με τίτλο "Mechanically Stabilized Earth (MSE) Wall Abutments for Bridge Support".

Το Εργαστήριο Εδαφομηχανικής και Θεμελιώσεων του Τμήματος Πολιτικών Μηχανικών ΔΠΘ προτίθεται να προτείνει στην Ελληνική Επιστημονική Εταιρεία Εδαφομηχανικής & Γεωτεχνικής Μηχανικής (ΑΕΓΜ) τη μελλοντική διοργάνωση παρόμοιων φοιτητικών διαγωνισμών στο πλαίσιο των πανελλήνιων γεωτεχνικών συνεδρίων.

Εικόνα 1. Προετοιμασία διαγωνισμού στις εγκαταστάσεις του Εργαστηρίου Εδαφομηχανικής και Θεμελιώσεων του Τμήματος Πολιτικών Μηχανικών ΔΠΘ.

Εικόνα 2. Διάστρωση και συμπύκνωση οπλισμένου εδάφους από τους φοιτητές.

Εικόνα 3. Φόρτιση δοκιμίου μετά την αφαίρεση του ξύλινου κιβωτίου.

---

[1] Η IACES είναι μία μη κερδοσκοπική διεθνής οργάνωση φοιτητών πολιτικών μηχανικών που δραστηριοποιείται από το 1989 και η οποία απαρτίζεται από τοπικές κοινότητες σε διάφορες χώρες του κόσμου. Στόχος της οργάνωσης είναι η δημιουργία μίας διεθνούς πλατφόρμας φοιτητών πολιτικών μηχανικών που προωθεί την ενδυνάμωση των σχέσεων μεταξύ των χωρών και την επιμόρφωση των συμμετεχόντων στο αντικείμενο του πολιτικού μηχανικού.

☙ ❧

The Doctoral Programme in Civil Engineering offers an outstanding opportunity for top PhD candidates

The Institute for Sustainability and Innovation in Structural Engineering (ISISE) and the Territory, Environment and Construction Research Centre (CTAC) aim to attract top students to their Doctoral Programme in Civil Engineering. In this context, they have established two grants specifically designed to offer talented and motivated students the opportunity to enroll in this PhD Programme offered by the School of Engineering of the University of Minho, either by receiving a full grant or by tuition waiving. These grants will be offered in each application period, subjected to availability of funding.

The Doctoral Programme in Civil Engineering is Accredited by the Agency for Assessment and Accreditation of Higher Education - A3ES, in recognition of the excellency of the staff and research facilities.

Application conditions are available at the programme website: www.pdec.civil.uminho.pt. **Deadline for application is December 15th.**

Contact:

Ms. Mariana Moreira-Freitas
Secretariado Programa Doutoral em Engenharia Civil
Universidade do Minho
Azurém
4800-058 Guimarães
Tel. +351 253 510 743 Fax. +351 253 510 217
www.pdec.civil.uminho.pt

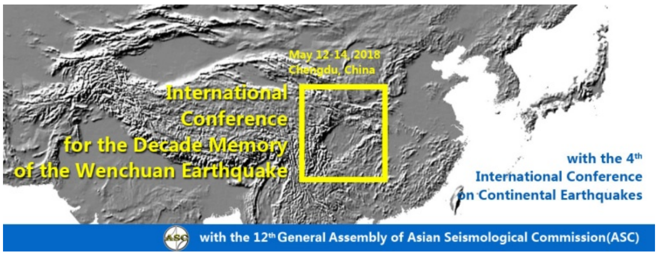
ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

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

ASIA 2018 Seventh International Conference and Exhibition on Water Resources and Renewable Energy Development in Asia, 15 March 2018, Danang, Vietnam, www.hydropower-dams.com/asia-2018-conference.php?c_id=303

World Tunnel Congress 2018 "The Role of Underground Space in Future Sustainable Cities", 20-26 April 2018, Dubai, United Arab Emirates, www.wtc2018.ae

☙ ❧



International Conference for the Decade Memory of the Wenchuan Earthquake

International Symposium on Seismic Safety of Large Dams and Reservoirs

12-14 May 2018, Chengdu, Sichuan, China

www.4thicce.com

Large dams were the first structures, which have been designed against earthquakes in almost all parts of the world since the 1930s. Until now, especially after the construction of a number of high dams, seismic safety of dams is still further a hot point worth to be focused on.

2018 is the 10th anniversary of the Wenchuan earthquake in China. International Conference for the decade memory of the "Wenchuan Earthquake", organized by China Earthquake Administration (CEA) in collaboration with several national and international organizations such as CHINCOLD, CSHE, IASPEI, ASC, ACES and NSFC, will be held on May 12-14, 2018, in Chengdu, Sichuan. As a session of the conference, the International Symposium on Seismic Safety of Large dams and reservoirs, organized by CHINCOLD and CSHE will be held meanwhile. International well-known experts on high dam seismic safety will attend the symposium and make keynote presentations. The Conference will provide all of us a good opportunity for fostering innovative ideas and productive cooperation.

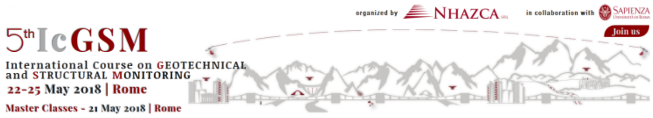
Conference Topics

- Seismic ground motion of dam site;
- Seismic design standard of high dams;
- Theory and method of seismic analysis of high dams;
- Seismic test method and technology for high dams;
- Dynamic characteristics of dam materials;
- Site test and health diagnosis for high dams;
- Post earthquake evaluation of dam safety & Repair and reinforcement technology;
- Research on prediction and monitoring of reservoir earthquake ;
- Dynamic analysis theory, method and seismic design of slope and underground structure

Correspondence Address

Mr. Lifeng Zheng (Dr.)
Secretariat of Chinese National Committee on Large Dams
Room 1266, IWHR Building A, A1 Fuxing Rd., Beijing 100038, P.R. China
Tel: +86-10-68585310
Fax: +86-10-68712208
Email: chincold-en@vip-126.com

☙ ❧



5th International Course on Geotechnical and Structural Monitoring

22 - 25 May 2018, in Rome

www.geotechnicalmonitoring.com

We are pleased to announce the official dates of the 5th International Course on Geotechnical and Structural Monitoring! The course will be held on 22 - 25 May 2018, in Rome. The 2017 IcGSM has been full of changes, contents and new ideas. We've decided not to stop here! Our challenge is to make the course better year by year, as regard both the logistics and the technical issues.

The International Course on Geotechnical and Structural Monitoring is growing year by year since its first edition in 2014 and, up to now, more than 450 attendees improved their technical knowledge with us!

40 international leaders have joined the courses as invited speakers and have presented their interesting projects from all around the world. In addition, the courses have become a great platform for other speakers to present new trends and case histories.

In 2017 we moved from Tuscany to Rome, allowing easier access and an increase in the available seating space for registrants. The attractiveness of the "Eternal City" was also a plus! We organized a field trip to the historical center of Rome, allowing participants to see a challenging geotechnical and structural monitoring program during construction of a new Metro Line that requires preservation of one of the most famous archeological sites in the world.

2017 was also the first year for the Master Classes (2h 30min. each) about various monitoring methods. Each class covered the following main topics: installation, data acquisition, data processing, tricks and tips from everyday experience, with opportunity for discussion. In 2018 we are planning to organize even more Master Classes!

Please keep your agenda free for the 5th International Course on Geotechnical and Structural Monitoring… and find out the news that will come soon!"

John Dunnicliff and Paolo Mazzanti

The IcGSM is an interactive event that encourage communication and exchange of ideas. You will have the chance to share your experience with the attendees of the 5th International Course on Geotechnical and Structural Monitoring.

Present your work during the participants' sessions, by submitting your abstract within the 28th February 2018!

Contacts

Nhazca s.r.l.
Via Vittorio Bachelet 12
00185 - Rome (ITALY)
Τελ. +39 06 9506 5820
info@nhazca.com
www.nhazca.com
Skype: nhazca

EUROCK 2018 Geomechanics and Geodynamics of Rock Masses, 22-26 May 2018, Saint Petersburg, Russia, www.eurock2018.com/en

4th GeoShanghai International Conference, May 27-30, 2018, Shanghai, China, http://geo-shanghai.org

XVI Danube-European Conference on Geotechnical Engineering: Geotechnical Hazards and Risks: Experiences and Practices, 7 - 9 June 2018, Skopje, Former Republic of Yugoslav www.decge2018.mk

16th European Conference on Earthquake Engineering (16thECEE), 18-21 June 2018, Thessaloniki, Greece, www.16ecee.org

CPT'18 4th International Symposium on Cone Penetration Testing, 21-22 June 2018, Delft, Netherlands, www.cpt18.org

NUMGE 2018 9th European Conference on Numerical Methods in Geotechnical Engineering, 25-27 June 2018, Porto, Portugal, www.numge2018.pt

RockDyn-3 - 3rd International Conference on Rock Dynamics and Applications, 25-29 June 2018, Trondheim, Norway, www.rocdyn.org

ICOLD 2018 26th Congress – 86th Annual Meeting, 1 - 7 July 2018, Vienna, Austria, www.icoldaustria2018.com

GeoChine 2018 - 5th GeoChina International Conference Civil Infrastructures Confronting Severe Weathers and Climate Changes: From Failure to Sustainability, July 23-25, , HangZhou, China, http://geochina2018.geoconf.org

UNSAT2018 The 7th International Conference on Unsaturated Soils, 3 - 5 August 2018, Hong Kong, China, www.unsat2018.org

CRETE 2018 6th International Conference on Industrial & Hazardous Waste Management, 4-7 September 2018, Chania, Crete, Greece, www.hwm-conferences.tuc.gr

SAHC 2018 11th International Conference on Structural Analysis of Historical Constructions "An interdisciplinary approach", 11-13 September 2018, Cusco, Perú http://sahc2018.com

11th International Conference on Geosynthetics (11ICG), 16 - 20 Sep 2018, Seoul, South Korea, www.11icg-seoul.org

CHALK 2018 Engineering in Chalk 2018, 17-18 September 2018, London, U.K., www.chalk2018.org

HYDRO 2018 ~ Progress through Partnerships
15-17 October 2018, Gdansk, Poland
www.hydropower-dams.com/hydro-2018.php?c_id=88

HYDRO 2018 will be the 25th in Aqua-Media's series of international events hosted in Europe, and will once again be the most significant conference and exhibition of the year for the global hydropower community. The annual conferences have become renowned as the most international gatherings in the profession, with delegations representing all countries with major hydro development programmes underway. An exchange of experience is encouraged on practical and topical issues, and an international steering committee works with the Aqua-Media team to ensure the high quality of papers accepted.

The event will bring together delegations from around 75-80 nations, sharing the common interest of advancing hydro development in all parts of the world. Lessons from past experience will be reviewed, achievements will be showcased, and new challenges will be tackled. The conference sub-title 'Progress through Partnerships' highlights the underlying theme of international collaboration which will be the basis for discussions. The location aims to facilitate participation from more countries in the Central Asian and eastern European region.

Emphasis will be on helping the less developed countries to unlock their hydro potential to advance socio-economic development, on cross-border collaboration and regional projects, and on maximising the potential to increase hydro capacity in the industrialized countries. Timely maintenance of existing hydro assets is another key theme, along with designing for the sustainability of greenfield projects.

MAIN CONFERENCE THEMES

Development opportunities

- Hydro potential and development plans
- Regional sessions
- Retrofitting and upgrading

Technical innovation

- New developments in large and small hydro machinery
- Modelling and testing
- Marine technology
- Operational issues

• Environmentally friendly machines

International collaboration

• Cross-border projects and power trading
• Regional planning
• The role of power pools
• Technology transfer

Environmental and social aspects

• Impact assessment and mitigation measures
• Protecting flora and fauna
• Greenhouse gas emissions
• Stakeholder communications
• Resettlement programmes

Hazard and risk

• Climate resilience: policies and practical plans
• Flood mitigation and management
• Earthquakes and landslides: lessons from past incidents
• Emergency planning
• Cyber security
• Powerplant safety
• Challenging sites

Civil engineering

• Dam design and construction
• Materials for dams
• Intakes, gateworks and spillways
• Dam safety and monitoring
• Alkali aggregate reaction
• Refurbishment of civil structures
• Safety of workers on site

Training and capacity building

• Review of training needs and new approaches
• Student programmes and succession planning
• Raising awareness of the engineering profession
• Experiences of young engineers
• Capacity building in the less developed countries

Project finance and contractual issues

• Progress in attracting private finance
• Legal and insurance issues
• Risk allocation and management
• Public-private partnerships
• Innovative contractual arrangements
• Valuing hydropower services

Pumped storage

• Innovative technology
• Benefits to the grid: case studies
• Developments in machinery
• New planned projects

Extending the life of hydro assets

• Condition monitoring
• Operation and maintenance
• Timely refurbishment
• Case studies

Sedimentation management

• Design measures to avoid siltation
• Sediment removal systems
• Case studies

Small and low-head hydro

• New developments in machinery
• Isolated schemes for rural electrification
• Low cost technology
• Innovative civil works

Communication

HYDRO 2018,
Mrs Margaret Bourke,
Conference Project Manager,
Aqua~Media International,
PO Box 285, Wallington, Surrey SM6 6AN, UK.
Tel: +44 20 8773 7244
Fax: + 44 20 8773 7255
Email: Hydro2018@hydropower-dams.com

ARMS10 - 10th Asian Rock Mechanics Symposium, ISRM Regional Symposium, 29 October - 3 November 2018, Singapore, www.arms10.org

ACUUS 2018 16th World Conference of Associated research Centers for the Urban Underground Space "Integrated Underground Solutions for Compact Metropolitan Cities", 5 – 7 November 2018, Hong Kong, China, www.acuus2018.hk

GeoMEast 2018 International Congress and Exhibition
"Sustainable Civil Infrastructures: Structural Integrity"
November 24 to 28, 2018, Cairo, Egypt
https://geomeast.org

On behalf of the Organizing Committee, we are pleased to invite you to attend the GeoMEast 2018 International Congress and Exhibition to be held in Cairo, Egypt from November 24 to 28, 2018. The GeoMEast SERIES is managed by SSIGE and supported by a number of leading international professional organizations.

Recent rapid construction in Egypt and the Middle East has provided great opportunities for bridge, pavement, geotechnical, geological, tunnel and all engineers to use their knowledge and talents to solve many challenging problems involving highways, bridge structures, pavements, materials, ground improvements, slopes, excavations, dams, canals and tunnels with innovative solutions and cutting-edge technologies.

GeoMEast 2018 will provide a showcase for recent developments and advancements in design, construction, and safety Inspections of transportation Infrastructures and offer a forum to discuss and debate future directions for the 21st century. Conference topics cover a broad array of contemporary issues for professionals involved in bridge, pavement, Geomechanics, geo-environmental, geotechnical, geosciences, geophysics, tunnel, water structures, railway and emerging techniques for safety inspections. You will have the opportunity to meet colleagues from all over the world for technical, scientific, and commercial discussions.

The proceedings of GeoMEast 2018 will be published in some Edited Books in SUCI Book Series by Springer-DE, which will be indexed in EI and submitted for inclusion in ISI "Thomson Reuters". In addition, some journal special issues will be published in some prestigious journals from selected best papers of the conference, however, authors need to expand and include materials that are at least 50:75% different than the accepted papers in the proceedings.

GeoMEast 2018 will provide some awards; such as: best paper awards, best presenter awards, best student presenter awards, industrial project, and others.

The program will include Podium Presentations, Poster Presentations, Keynote Lectures, Workshops, Courses, Awards, Technical Meetings, and Technical and Social Tours.

On behalf of the organizing committee,
General Secretariat

Dr. Eng. Hany Farouk Shehata; CEO, SSIGE

Technical Themes

Geotechnical, Geological, Geoenvironmental and Geosynthetics:

- Geotechnical, Geoenvironmental and Earthquake Geotechnical Engineering;
- Soil and Rock Mechanics, Geomechanics, Mining, and Geological engineering;
- Geosynthetics and Reinforced Soil Retaining Structures;
- Behavior, Identification and In-situ Test Methods for Site Characterization of Soils, and Lateritic, Problematic, Collapsible, Swelling, Soft, Sabkha and Uncommon Soils;
- Design and Quality Control of Earth Structures and Subgrades;
- Soil Stability and Landslide, Ground improvement and Seismic Hazards;
- Soil-Structure Interaction, Advanced Analysis of Shallow and Deep Foundations, Foundation Failure and Repair, and MicroPiles and its innovative applications;
- Computational Mechanics, Innovative Soil Models, Discrete Element and Boundary Element Modelling, Mesoscale Modeling, and Advanced Numerical and Analytical Analyses;
- Physical Modelling in Geotechnics;
- Saturated and Unsaturated Soil Mechanics;
- Oil and Gas, and Petroleum Geotechnical Engineering; and
- Geosciences, Geomatics, Geoinformatics, Geophysics and Global Hazards.

Sustainable Civil Infrastructures:

- **Structures and Bridges Engineering:**
- Advanced Analysis of Structures;
- Non-Destructive Evaluation;
- Inspection Technologies;
- Structural Health Monitoring;
- Remote Monitoring of Structures;
- Scour Assessment;
- Seismic Design Issues for Bridges, Super Structures and Underground Structures;
- Design Methods and Materials, Innovative Repair Methods and Materials, Durable and Sustainable Designs, Innovative Materials, Advances in Foundation Design/ Construction, Accelerated and/or Performance Based Design/Construction, Aesthetics and Environment;
- State-of-the-Arts and State-of-the-Practices on Bridge Design, Construction and Maintenance;
- Special Foundation Treatment and Settlement Control Technology.
- **Tunneling Engineering:**
- Tunnel Management and Inventory, Monitoring and Settlement Control;
- Emerging Technologies, Lining Design & Precast Segment Advances;
- Innovation in Tunneling Design, Construction, Repair, Rehabilitation;
- Fire & Life Safety, Vulnerability & Security;
- Tunneling in Soft Ground, Ground Conditioning and Modification;
- Advanced prediction technology of tunnel construction geology;
- Deep excavations and urban tunneling.
- **Pavement Engineering, Airports and Advances in Pavement Techniques:**
- Airfield pavement analysis, rehabilitation and performance;
- Recycled Asphalt Pavement; Pavement Design, Modeling, Performance Evaluation, & Management;
- Sustainable Long Life Pavement; Ground Improvement, and Chemical/Mechanical Stabilization for Pavement and Geotechnical Applications;
- Moisture Damage in Asphaltic Concrete Materials; Pavement Foundations: Modelling, Design and Performance Evaluation;
- Geotechnical Properties and Their Effects on Portland Concrete Pavement Behavior and Performance; Warm Mix;
- Rehabilitation strategy selection and preventative maintenance treatments;
- Accelerated Testing of Pavement Structures and Materials;
- Material, Design, Construction, Maintenance and Testing of Pavement;
- Asphalt Binder and Mixture Characterization;
- Construction and Rehabilitation of Jointed Concrete Pavement, Reinforced Concrete Pavement, and Continuously Reinforced Concrete Pavement;
- Bridges Deck Pavement; Stabilization, Recycling, Foamed Bitumen and Emulsion, Granular Materials;
- Roadway Widening; Asphalt Mix-Design, HMA;
- Testing & Material; Property Characterization.
- **Transportation Engineering:** Highway Pavements: Design, Materials, and Construction; Transportation Operations and Safety; Advanced Technologies, Infrastructure Systems, Intermodal Transportation, Planning, and Development; Rail and Transit; Aviation
- **Railroad and Railway Engineering:**
- Railway and Railroad Track Substructure;
- High Speed Rail System;
- Seismic Design for Railway and Roadway Structures;
- Economics of Railway Engineering and Operations;
- Structures, Maintenance and Construction;
- Innovative Procedures and Precautions;
- Long Term Pavement Performance Contest;
- BIM and Contract Administration.
- **Engineering geology for urban and major infrastructure development:**

  The ongoing population growth is resulting in rapid urbanization and new infrastructure development. This, together with the current climate change and increasing impact of natural hazards, imply that the engineering geology profession is called upon to respond to new challenges. It is recognized that these challenges are particularly relevant in the developing and newly industrialized regions. The idea beyond this Theme is to highlight the role of engineering geology in fostering sustainable urbanization and infrastructure construction (e.g., major buildings and facilities, water supply and distribution systems, roads, railways, tunnels, ports, dams, powerlines, pipelines). We invite contributions that illustrate how engineering geologists can support civil, geotechnical and environmental engineers in different phases of infrastructure development including sustainability assessment, pre-design site investigation, design and construction. Papers related to ageing infrastructure maintenance, structural stability control and monitoring, environmental impact studies and protection from geo-hazards are also welcome.

- **Dams Engineering, Canals and Levees, Irrigation and Water Sources and Structures, and Ports, Offshore and Marine Technologies.**

Climate Change and effects on Infrastructure:

- **Sustainability and Energy Engineering;**
- **Environmental and Waste / Sediment Management, Characterization, Treatment and Re-Use;**
- **Energy Geotechnics and Geo-Energy Infrastructure.**
- **Materials Engineering, Nanotechnologies, Advances in Composite Materials, Climate-Friendly Technologies, and Damage Mechanics.**
- **Structural Health Monitoring, and Sustainable Construction Technologies;**
- **Advanced Analysis for Sustainable Design.**
- **Worldwide innovative procedures and precautions for the Design;**
- **Building Information Modeling (BIM), Building and Construction Engineering, Project Management, and Contract Administration; and**
- **Sustainable Infrastructure:** Current and Projected; Financing Infrastructure Projects; Cross-cutting Issues; Materials, Tools, and Methodologies; Innovation; Sustainability and Competitiveness; Risk, Resiliency, and Adaptation to Climate Change; Sustainable Cities; Sustainability, Society and Culture; Envision™ and Other Rating Systems; Special Topics on Middle East Urbanization; Smarthome, barrier-free building and reconstructing

Contact:

Info@GeoMEast2018.org, Info@SSIGE.org
Tel. +201110666775

cs &

WTC2019 Tunnels and Underground Cities: Engineering and Innovation meet Archaeology, Architecture and Art and ITA - AITES General Assembly and World Tunnel Congress, 3-9 May 2019, Naples, Italy, www.wtc2019.com

cs &

7 ICEGE 2019

International Conference on Earthquake Geotechnical Engineering
17 - 20 June 2019, Rome, Italy

Organizer: TC203 and AGI (Italian Geotechnical Society)
Contact person: Susanna Antonielli
Address: AGI - Viale dell' Università 11, 00185, Roma, Italy
Phone: +39 06 4465569
Fax: +39 06 44361035
E-mail: agi@associazionegeotecnica.it

cs &

ISDCG 2019

7th International Symposium on Deformation Characteristics of Geomaterials
26 - 28 June 2019, Glasgow, Scotland, UK,

The Technical Committee 101 of the ISSMEG is pleased to announce the organisation of the 7th International Symposium on Deformation Characteristics of Geomaterials (ISDCG) in 2019, in Glasgow, UK. The symposium is co-organised by the University of Strathclyde in Glasgow, the University of Bristol, and the Imperial College in London.

Building on the success of the previous Symposia organised in Sapporo (Japan) Japan in 1994, Torino (Italy) in 1999, Lyon (France) in 2003, Atlanta (US) in 2008, Seoul (Korea) in 2011 and Buenos Aires (Argentina) in 2015, the 7th ISDCG will equally follow both its traditions and active promotion of new technical elements to maintain it as one of the most popular and vibrant events within the geotechnical community. The technical core themes will focus on: (i) advanced laboratory geotechnical testing; (ii) application of advanced laboratory testing in research, site characterisation, and ground modelling; (iii) application of advanced testing to practical geotechnical engineering. In addition to these traditional topics, sub-themes will include cutting-edge techniques and approaches, for example experimental micro-mechanics, non-invasive monitoring systems, nano and micro-sensors, new sensing technologies. A key goal is to engage with the full spectrum of geotechnical specialists, from early career engineers and researchers through to world leading experts.

cs &

The 17th European Conference on Soil Mechanics and Geotechnical Engineering

1st - 6th September 2019, Reykjavik Iceland
www.ecsmge-2019.com

The theme of the conference embraces all aspects of geotechnical engineering. Geotechnical engineering is the foundation of current as well as future societies, which both rely on complex civil engineering infrastructures, and call for mitigation of potential geodangers posing threat to these. Geotechnical means and solutions are required to ensure infrastructure safety and sustainable development. Those means are rooted in past experiences enhanced by research and technology of today.

At great events such as the European Geotechnical Conference we should: Spread our knowledge and experience to our colleagues; Introduce innovations, research and development of techniques and equipment; Report on successful geotechnical constructions and application of geotechnical design methods, as well as, on mitigation and assessment of geohazards and more.

Such events also provide an opportunity to draw the attention of others outside the field of geotechnical engineering to the importance of what we are doing, particularly to those who, directly or indirectly, rely on our services, knowledge and experience. Investment in quality geotechnical work is required for successful and safe design, construction and operation of any infrastructure. Geotechnical engineering is the key to a safe and sustainable infrastructure and of importance for the society, economy and the environment. This must be emphasized and reported upon.

cs 80

14th ISRM International Congress, 13-18 September 2019, Iguassu Falls, Brazil, www.isrm2019.com

XVI Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, 21 - 25 October 2019, Taipei, China www.16arc.org

XVI Panamerican Conference on Soil Mechanics and Geotechnical Engineering, 18-22 November 2019, Cancun, Quintana Roo, Mexico, http://panamerican2019mexico.com/panamerican

cs 80

Nordic Geotechnical Meeting
27-29 May 2020, Helsinki, Finland

Contact person: Prof. Leena Korkiala-Tanttu
Address: SGY-Finnish Geotechnical Society,
Phone: +358-(0)50 312 4775
Email: leena.korkiala-tanttu@aalto.fi

12 of the World's Most Fascinating Dams

There are many jaw-dropping structural feats around the world that have their own interesting engineering designs. But the one type of structure that would always leave me in great awe are dams. Their sheer dimension and immense capacity have this humbling effect on anyone that would come across this structure. It's literally like standing in front of a calm, reassuring giant staring at you in all its glory. And it goes without saying, dams are one of the most intricately designed structures in the world. Here, you will discover some of the largest and groundbreaking dams around the globe, which have become producers of sustainable energy.

Contra Dam (Switzerland)

First on my list of fascinating dams would have to be the Contra Dam or most commonly known as the Verzasca Dam in Ticino, Switzerland. It is perhaps most famous for its 1995 epic appearance in the opening scene of the James Bond movie GoldenEye.

Contra Dam is a slender concrete arch dam standing at a height of **220 m** with a crest length of **380 m**. Because of the dam's slender design, the volume of concrete required to construct it was reduced and consequently cutting down the cost of the infrastructure. The dam's base is **28 m** in width and gradually tapers up to **7 m** at the crest. Two spillways were incorporated at each side of the structure, which has a maximum discharge capacity of **1,300 cubic meters** per second. Contra Dam also produces power through its **105 MW** power station with **3x35 MW** Francis turbines that generates an average of **234 GWh** per year.

Lago di Vogorno is a reservoir that was created and now impounded by the dam when it was constructed between 1961-1965. This reservoir has a maximum capacity of **105,000,000 cubic meters** of water and a surface area of **400 acres**.

Gordon Dam (Australia)

Located in the southwest Tasmania in Australia, Gordon Dam is a double curvature concrete arch dam. One of the dam's amazing feature is that it's curved both in the vertical and horizontal directions to resist large hydraulic pressures coming from the **12,359,040 megaliters** of water in Lake Gordon, the largest lake in Australia. The immense volume of water is diverted **183 m** to the underground power station, where three hydro turbines can generate up to **432 MW** of power. Approximately **13%** of Tasmania's electricity demand is provided by the Gordon Power Station.

Out of the 48 arch dams that has been built in Australia, Gordon Dam is one of the only nine that is designed to be a doubly curving dam.

Monticello Dam (USA)

This **93 m** concrete arch dam in California, USA is one of the coolest dams in the world because of its mesmerizing spillway called the Glory Hole. The spillway is an uncontrolled morning glory type with a lip diameter of **22 m** and sits within the perimeters of Lake Berryessa, the seventh largest man-made lake in California. It can drain **48,400 cubic feet** per second of water during the lake's peak level that occurs when the lake rises to **4.7 m** above the spillway's lip. The exit end of the spillway is also famous as a full pipe for skateboarders.

Monticello dam impounds the Putah Creek that can generate **56,806,000 kWh** of power annually using **2x5 MW** and **1x1.5 MW** turbines.

Hoover Dam (USA)

Hoover Dam is one of the most iconic dams around the world stretching between the American states of Nevada and Arizona. Originally called the Boulder dam, this colossal structure stands at a height of **221.4 m**, with a base width of **200 m** and a crest width of **14 m**. It's a concrete gravity-arch dam that was constructed with the purpose to control flood, provide irrigation water, produce hydroelectric power, store water, and for recreation. The hydropower station houses various types of turbines like a **1x61.5 MW** Francis turbine and **2x2.4 MW** Pelton turbine, which produce an annual electrical output of **4.2 TWh.**

One of the biggest preparations done for the construction of Hoover Dam was the diversion of the Colorado river away from the site. To make this happen, four diversion tunnels were bored through the canyon walls - two on the Nevada side and two on the Arizona side. On the 1st of February, 1935, a few years after the Colorado river was diverted, a steel gate was lowered down to allow the water to take its natural course again. That was the first time in history when the Colorado river was under the control of man. The dam impounds the Colorado river which consequently forms Lake Mead, the largest reservoir by volume (when full) in the United States.

Three Gorges Dam (China)

Known as the world's largest hydropower dam, the Three Gorges dam stretches out **2.3 km** to span and impounds the Yangtze river in the Hubei province in China. Capable of producing **87 TWh** of electricity per annum, this hydropower dam uses **32x700 MW** and **2x50 MW** of Francis turbines. Its structural profile is designed with a large base width of **115 m** and tapers to **40 m** at the crest. Intended not only to produce electricity, the three Gorges Dam was also constructed to increase the shipping capacity of the Yangtze river and mitigate the chances of flooding downstream by providing large water storage space.

The most mind blowing fact about this dam is that it's capable of slowing the Earth's rotation by shifting immense volume of water.

Tarbela Dam (Pakistan)

Considered as the largest earth-filled dam in the world, the Tarbela Dam in Pakistan impounds the Indus river to serve as irrigation supply, flood control, and to produce hydroelectric power. In order to properly divert the Indus river, the dam's construction had to be done in three stages where large tunnels had to be constructed to act as diversion channels. The dam's main wall was built with earth and rock fill that spans for **2,743.2 m** from the island to the right-hand side of the river. Two concrete auxiliary dams span the river from the island to the left hand-side.

Equipped with **10x175 MW** and **4x432 MW** of turbines, Tarbela Dam is capable of producing **14.959 billion kWh** of electricity per annum.

Almendra Dam (Spain)

One of Spain's tallest structures, the Almendra Dam, literally translates to almond, is located in the country's province of Salamanca. Impounding the Tormes river, this concrete gravity arch dam is part of the hydroelectric system known as the Duero Drops. The Duero Drops system is composed of five dams from Spain and three other dams nearby Portugal. The spillway seen from the photo below can disperse water at a rate of **3,039 cubic meters** per second.

Itaipu Dam (Brazil)

This fascinating hydroelectric dam stretches **7, 919 m** from Brazil to Paraguay impounding the Parana river. It beats the Three Gorges Dam in terms of power output at an average of **89.5 TWh** per annum by using **20x700 MW** Francis turbines. Ten of the turbines generate power for Paraguay, while the other ten brings power to Brazil. Itaipu dam is, in fact, a series of four dams: a concrete wing dam, a main concrete dam, a rock-fill dam, and an earth-fill dam.

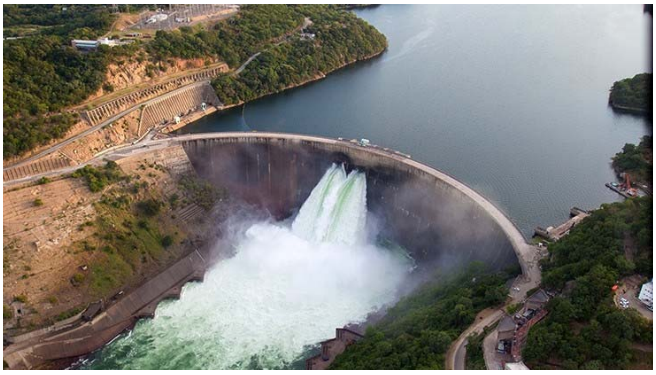
Impressively, the immense volume of concrete used in constructing the dam was properly cured using large refrigeration units equivalent to **50,000** deep freezers. Another mind blowing fact about this dam is that the Guaira Falls, once known as the world's most amazing water feature, was submerged under water when the Itaipu reservoir was filled. The Guaira Falls stood twice the height of Niagara falls and surged twice as much water.

Atatürk Dam (Turkey)

Located on the Euphrates river, the Atatürk Dam is the largest in Turkey and ranks sixth from the largest earth-and-rock filled embankment dams in the world. It is the centerpiece of the 22 dams that exist on the Euphrates and the Tigris, which comprise the integrated sectors of the Southeastern Anatolia Project, or GAP in Turkish (*Güney Doğu Anadolu Projesi*). The Atatürk reservoir has a capacity of **48.7 cubic kilometers** of water and equipped with **8x300 MW** Francis turbines, which generate **8,900 GWh** of electrical power per annum. The construction of the dam wiped out many important historical sites like the birthplace of the Ancient Greek poet Lucian.

Kariba Dam (Zimbabwe)

One of the largest in Africa, the Kariba Dam supplies **1,626 MW** of power to the Copperbelt parts of both Zambia and Zimbabwe. Impounding the Zambezi river, Kariba dam is outfitted with 10 types of Francis turbines capable of outputting an average of **6,400 GWh** of electrical power per year. The dam was designed as a double curvature concrete arch dam to effectively resist the **180 cubic kilometers** of water pressing against it.



Because of the immense volume of water from the created Kariba reservoir, over 6,000 animals had to be rescued by Operation Noah as the Kariba Gorge was flooded.

Kerr Dam (USA)

Designed for producing hydroelectricity, the Kerr Dam also serves as wildlife resources, forest conservation, and public recreational uses. By impounding the Flathead river, the dam is capable of producing **426 GWh** of electricity per annum. It is one of the two PPL Montana dams located west of the Continental Divide where the Flathead river cascadingly empties into the Clark Fork river, which subsequently empties into the Columbia river. Finally, the Columbia river empties right into the Pacific ocean.

Gariep Dam (South Africa)

The Gariep Dam was designed to be a hybrid gravity-arch dam as the gorge is too wide for a full arch. Gravity abutments are formed using flank walls then the design gradually arches at the center of the dam. It impounds the Orange river and creates the Gariep reservoir with a maximum capacity of **5,340,00 megaliters**. **899 GWh** of electrical power is produced by the dam annually using **4x90 MW** turbines. The Gariep Dam bridge is also visible from the photo below, where the Orange and Caledon rivers flow through as well the Braksprujt, Broekspruit, Oudagspruit, and Slykspruit streams.

There are many other dams around the world with their unique and fascinating engineering designs. So, if we've missed them then feel free to let us know in the comments section below.

(Kathleen Villaluz / INTERESTNG ENGINEERING, May, 21st 2017, https://interestingengineering.com/12-worlds-fascinating-dams)

Scifi Eye: Tunnels are inspiration for future worlds

Jon Wallace explores the scifi potential of the tunnel

To the 21st century citizen, the tunnel is one of those engineering accomplishments that's easily taken for granted, or barely noticed at all – unless it is as a source of disgruntlement: the British love to complain about their tunnels, either as frustrated commuters trapped in Dartford and Blackwall traffic, or as opponents to new projects. Excitement about new tunnels is equally limited: even the Channel Tunnel, an extraordinary achievement by any standard, is not cherished by the public as are our great bridges. Neither are the engines of tunnel construction: 'Victoria', the last machine used to excavate London's Crossrail, was picked to pieces underground and recycled, denied the museum space we so keenly reserve for other mechanical engineering heritage.

In much of science fiction, tunnels are the lairs of an alien menace

Despite the efforts of dreamers such as Elon Musk and his proposed network of underground highways, and astonishing achievements such as the Gotthard Base project, for many, the tunnel still lacks something in the aesthetic department. Rather than the horizon-straddling connection provided by a bridge, the tunnel is hidden away. Further, a bridge is almost uniquely a human innovation, where the tunnel 'merely' imitates the behaviour of our humbler animal kin: the worm, hag fish and gerbil. Or perhaps it's the tunnel's more unsavoury human connotations that detract from its appeal – as a means of intrusion: the favoured transportation of thief, smuggler, and sneak attacker. Well, when *The Engineer* reports on Norway's ambitious plans to build the world's first ship tunnel, the scifi eye, at least, likes what it sees. Tunnels make wonderful settings for story.

In much of science fiction, tunnels are the lairs of an alien menace, threatening the foundations of society: 1967's *Battle Beneath the Earth* sees Chinese invaders burrowing beneath the US laying atomic bombs; the bugs in Heinlein's *Starship Troopers* scurry beneath the surface of hostile planets; while the MUTO of 2014's *Godzilla* hatches below ground and burrows to the surface to wreak havoc. Often there's a nuclear element to these creatures' development, which is perhaps not an entirely absurd notion: our tunnels do breed new species. (Post-war studies found a new strain of mosquito in London's tube.) Bearing in mind US plans to store its nuclear waste in Yucca Mountain tunnels; and North Korea's fondness for detonating nukes in deep excavations, the scifi imagination is naturally fired by the thought of some hideous super mutant emerging from centuries of radioactive incubation.

Where the inhabitants of science-fiction tunnels are human, they still tend toward the outlandish: mole men, Morlocks and the 'crawlers' of Neil Marshall's *The Descent* play on primeval fears of being dragged back to our prehistoric, cave-dwelling roots. Where normal people are found in tunnel settings they tend to be explorers and scientists, in fables such as Verne's *Journey to the Centre of the Earth* and the ludicrous film *The Core*. More effective are tales where humanity has adapted to endure a tunnel world, such as Roger Levy's novel *Icarus*.

What other gloomy worlds might tunnels explore? The Chunnel itself inspires: what other fractious near-neighbours could be bound by future tubes – Japan and China? Argentina and the Falklands? Such tunnels need not only serve paranoid invasion fantasies, but great escapes too. Imagine a future Russian police state, where a group of future engineers is excavating a grand Soviet-style subway in Yakutsk. Determined to escape the clutches of their megalomaniacal dictator, they secretly reprogramme their boring machines to tunnel on, eastward, all the way to the Bering Strait and beyond to Alaska. Chased through the tunnel by a tipped-off secret police, they blow up the exit behind them: only to realise that their new home may not be quite what they imagined.

Boring machines might help colonise space. Self-assembling tunnelling robots might be the first to land on Mars, excavating underground habitats that avoid the perils of surface dwellings. One astronaut is sent to monitor their progress, but alone on Mars he goes mad, slowly dying from radiation sickness. Determined to find immortality, and inspired by the pharaohs, he reprogrammes his boring machines to excavate Olympus Mons, creating a huge pyramid in his honour: once complete they roam the passageways, ready to ambush any future Lord Carnarvon who comes raiding for treasure.

Or perhaps, finally, we should turn for inspiration to the seedier side of tunnelling: cartels use tunnels to smuggle product into the US. What of a future president who decrees drugs legal below the surface, literally driving the trade underground? A hugely expanded network of tunnels and caverns develops along the Mexican border, growing into a thriving shadow state. It is a dangerous territory, riven by petty theft and sporadic violence – but also the only place to go to hear good music.

(Jon Wallace / theengineer, 22nd May 2017, https://www.theengineer.co.uk/scifi-eye-tunnels-are-inspiration-for-future-worlds/?cmpid=tenews_3446175)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ

Seabed seismic sensors would have cut 2011 Japan tsunami toll

A new tsunami warning system could have saved many of the 22,000 people killed by the massive tsunami following the 2011 Tohoku earthquake in Japan, had it been in place there at the time.

That's the message from simulations assessing how the system – now installed elsewhere in Japan – would have responded to the Tohoku quake itself.

They show that the system, based on a network of cable-connected seismic and pressure sensors placed on the seabed along quake-prone faults, would have raised the alarm in 7 minutes or less. Following the quake, it actually took 30 minutes for alarms to be sounded.

"It would have provided an extra 23 minutes," says Yuichiro Tanioka of Hokkaido University, who presented the results last week at the annual meeting of the European Geosciences Union in Vienna, Austria.

Extra time

The earlier warning would have given residents along the Sanriku coast of north-east Japan precious extra time to reach high buildings and other shelters before the tsunami swept over. "Thousands had already been evacuated because of heavy foreshocks, but many of those who remained might have escaped," says Tanioka.

The system he evaluated is already in operation off the south-eastern coast of Japan, monitoring the quake-prone Nankai trough parallel to the coastline. Japan's National Institute of Disaster Prevention is now installing a network of 125 sensors 30 kilometres apart on the Japan trench that gave rise to the Tohoku quake, so Tanioka used data from the Nankai system to predict how the new one would have performed in 2011.

By combining pressure and seismic readings from the sensors with existing data on typical tsunami waveforms, quake-induced sea floor deformations detected by satellites, and data from previous large quakes, Tanioka devised an algorithm to instantly work out the likely tsunami size, which sections of the coastline would be flooded, and how soon.

First, he showed that within minutes, the algorithm very accurately predicted the pattern of flooding seen following tsunamis tracked by the Nankai system.

Then, using input from that "test run", he simulated how the new, 125-sensor "S-NET" system being installed on the Japan trench would have reacted to the Tohoku quake. He found that it accurately predicted, again within minutes, the scale and location of actual flooding. "The time to predict the tsunami inundation is about 2 to 4 minutes after the tsunami is generated," he says.

Automatic alarm

To issue swift, accurate warnings, "we wouldn't need any information on the earthquake", he says. Instead, the sensor system would simulate likely flooding based on its incoming seismic and pressure data, and activate the alarm automatically if a tsunami was imminent.

Tanioka says that the accuracy of the system needs to be improved further still, but is confident it will provide a faster way to raise the alarm wherever it's installed. "It could save thousands of lives in the future," he told *New Scientist*.

"When you evacuate, every minute counts, and even 5 minutes can be crucial," says Costas Synolakis of the Tsunami Research Center at the University of Southern California, who heard Tanioka's presentation.

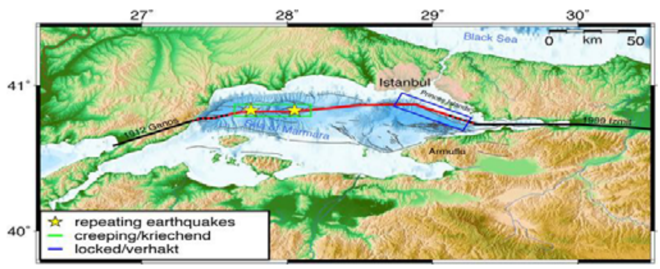
Synolakis says that the new sensor systems could work well in Japan where tsunamis strike rapidly because they often originate close to the coast. In the US, however, existing warning systems based on deep buoys already work well because most of the tsunamis that arrive there come from far away, such as Chile or Japan, giving much more time to react.

Synolakis also questions whether earlier warnings would have saved many more lives after Tohoku, because evacuation centres had been built to cope with magnitude 7.5 incidents rather than the magnitude 8.9 quake. "Even if with a faster warning, if the planning is wrong, many will die," he says.

(Andy Coghlan / DAILY NEWS, 1 May 2017, https://www.newscientist.com/article/2129373-seabed-seismic-sensors-would-have-cut-2011-japan-tsunami-toll)

ᴓᴓ ᴓᴓ

From where will the next big earthquake hit the city of Istanbul?



Marmara Sea region in northwestern Turkey with the North Anatolian Fault Zone (NAFZ) separating Eurasia from Anatolian. The offshore Marmara fault where a major earthquake is overdue is indicated by the red line. The black lines to either side are the two last major ruptures of the region, the 1912 Ganos and the 1999 Izmit earthquakes. The Marmara section has not produced a large earthquake since

1766 but is know to rupture every ~250 years based on historical records. The yellow stars mark the repeating earthquakes found in the now published study indicating fault creep (green rectangle) while the fault portion offshore of Istanbul (blue rectangle) is locked.

The city of Istanbul is focus of great concern for earthquake researchers. This 15-million metropole is situated very close to the so-called North Anatolian Fault Zone which runs just outside of the city gates below the Marmara Sea. Here in the underground there is a constant build-up of energy which results from an interlocking of the tectonic plates causing plate movement to come to a halt until a great tremor releases this energy. Scientists, therefore, reckon with an earthquake with a magnitude of 7 or greater in this region in the coming years.

The extent of such seismic threat to this Turkish city of Istanbul actually depends on how strongly the plates are entangled and on the exact nucleation point of the earthquake. A team led by Marco Bohnhoff from the GFZ German Research Centre for Geoscience now presents a study indicating that the next major earthquake is more likely to originate in Istanbul's eastern Marmara Sea. "*This is both good news and bad news for the city with over 15 million inhabitants*". The good news: "*The rupture propagation will then run eastwards i.e. away from the city*", explains the researcher. "*The bad news is that there will only be a very short early warning phase of a few seconds.*" Early warning times are extremely important in order to switch traffic lights to red, to block tunnels and bridges or to shut down critical infrastructure. The research results are now published in the scientific journal *Geophysical Journal International*.

The estimations presented by Marco Bohnhoff and his team are based on the analysis of numerous small quakes along the Marmara fault. Results have shown that the degree of locking in the western part of the fracture zone is lower and that the two tectonic plates are creeping past one another at a very slow rate. During this process small tremors of the same signature, so-called "repeaters", occur at distinct recurrence times. Further east, close to Istanbul, however, repeaters have not been observed and the tectonic plates appear to be completely locked here. This leads to a build-up of tectonic energy and increases the probability of a large earthquake there.

Such observations were possible due to a new high-precision seismicity catalog for the region. For this purpose, the researchers have thoroughly evaluated the earthquake activity by combining the two major Turkish Earthquake Measurement Networks with measurement data from the GFZ Plate Boarder Observatory within the framework of a German-Turkish cooperation project. "*In this way we have found recurring earthquakes below the western Marmara Sea*" says Bohnhoff. "*From this we deduce that below the western Marmara Sea the two tectonic plates (for the most part -- 25-75%) are moving slowly past each other thus accumulating less energy than if they were completely locked.*"

And what will happen if it actually comes to the feared strong earthquake below the western Marmara Sea? "*In such a case there would likewise be good news and bad news,*" says Bohnhoff. Good would be a somewhat longer early warning period, bad would be the fact that the rupture propagation would then take place in the direction of Istanbul resulting in more severe ground shaking than if the origin was further east. However, the current data obtained suggests the opposite: an earthquake with an epicenter at the gates of the city, which would allow the people only very little time to find protection, but which would trigger less powerful ground movements.

Original study: Bohnhoff, M., Wollin, C., Domigall, D., Küperkoch, L., Martínez-Garzón, P., Kwiatek, G., Dresen, G., Malin, P.E., 2017. Repeating Marmara Sea Earthquakes: Indication for fault creep. *Geophysical Journal International* 169, DOI: 10.1093/gji/ggx169

(GFZ German Research Centre for Geosciences, Helmholtz Centre, Potsdam, 17 May 2017, http://www.gfz-potsdam.de/en/media-communication/news/details/article/von-wo-aus-wird-das-ueberfaellige-grosse-beben-istanbul-treffen/)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

What Would Happen If Yellowstone's Supervolcano Erupted?

Hot springs in Yellowstone National Park are just one of the types of thermal features that result from volcanic activity.

Although fears of a Yellowstone volcanic blast go viral every few years, there are better things to worry about than a catastrophic supereruption exploding from the bowels of Yellowstone National Park.

Scientists at the U.S. Geological Survey's (USGS) Yellowstone Volcano Observatory always pooh-pooh these worrisome memes, but that doesn't mean researchers are ignoring the possible consequences of a supereruption. Along with forecasting the damage, scientists constantly monitor the region for signs of molten rock tunneling underground. Scientists scrutinize past supereruptions, as well as smaller volcanic blasts, to predict what would happen if the Yellowstone Volcano did blow.

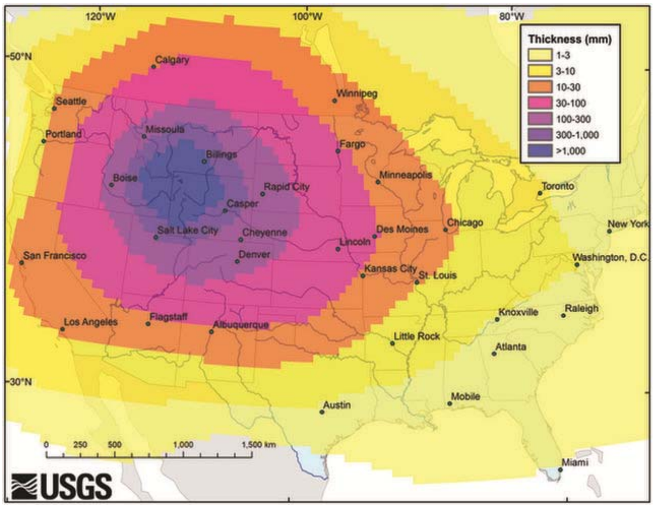
Here's a deeper look at whether Yellowstone's volcano would fire up a global catastrophe.

Probing Yellowstone's past

Most of Yellowstone National Park sits inside three overlapping calderas. The shallow, bowl-shaped depressions formed when an underground magma chamber erupted at Yellowstone. Each time, so much material spewed out that the ground collapsed downward, creating a caldera. The massive blasts struck 2.1 million, 1.3 million and 640,000 years ago. These past eruptions serve as clues to understanding what would happen if there was another Yellowstone megaexplosion.

If a future supereruption resembles its predecessors, then flowing lava won't be much of a threat. The older Yellowstone lava flows never traveled much farther than the park boundaries, according to the USGS. For volcanologists, the biggest worry is wind-flung ash. Imagine a circle about 500 miles (800 kilometers) across surrounding Yellowstone; studies suggest the region inside this circle might see more than 4 inches (10 centimeters) of ash on the ground, scientists reported Aug. 27, 2014, in the journal Geochemistry, Geophysics, Geosystems.

The ash would be pretty devastating for the United States, scientists predict. The fallout would include short-term destruction of Midwest agriculture, and rivers and streams would be clogged by gray muck.



An example of the possible ash fall from a month-long Yellowstone supereruption.

People living in the Pacific Northwest might also be choking on Yellowstone's fallout.

"People who live upwind from eruptions need to be concerned about the big ones," said Larry Mastin, a USGS volcanologist and lead author of the 2014 ash study. Big eruptions often spawn giant umbrella clouds that push ash upwind across half the continent, Mastin said. These clouds get their name because the broad, flat cloud hovering over the volcano resembles an umbrella. "An umbrella cloud fundamentally changes how ash is distributed," Mastin said.

But California and Florida, which grow most of the country's fruits and vegetables, would see only a dusting of ash.

A smelly climate shift

Yellowstone Volcano's next supereruption is likely to spew vast quantities of gases such as sulfur dioxide, which forms a sulfur aerosol that absorbs sunlight and reflects some of it back to space. The resulting climate cooling could last up to a decade. The temporary climate shift could alter rainfall patterns, and, along with severe frosts, cause widespread crop losses and famine.

The walls of the Grand Canyon of Yellowstone are made up predominantly of lava and rocks from a supereruption some 500,000 years ago.

But a Yellowstone megablast would not wipe out life on Earth. There were no extinctions after its last three enormous eruptions, nor have other supereruptions triggered extinctions in the last few million years.

"Are we all going to die if Yellowstone erupts? Almost certainly the answer is no," said Jamie Farrell, a Yellowstone expert and assistant research professor at the University of Utah. "There have been quite a few supereruptions in the past couple million years, and we're still around."

However, scientists agree there is still much to learn about the global effects of supereruptions. The problem is that these massive outbursts are rare, striking somewhere on Earth only once or twice every million years, one study found. "We know from the geologic evidence that these were huge eruptions, but most of them occurred long enough in the past that we don't have much detail on what their consequences were," Mastin said. "These events have been so infrequent that our advice has been not to worry about it."

A far more likely damage scenario comes from the less predictable hazards — large earthquakes and hydrothermal blasts in the areas where tourists roam. "These pose a huge hazard and could have a huge impact on people," Farrell said.

Supereruption reports are exaggerated

Human civilization will surely survive a supereruption, so let's bust another myth. There is no pool of molten rock churning beneath Yellowstone's iconic geysers and mud pots. The Earth's crust and mantle beneath Yellowstone are indeed hot, but they are mostly solid, with small pockets of molten rock scattered throughout, like water inside a sponge. About 9 percent of the hot blob is molten, and the rest is solid, scientists reported on May 15, 2015, in the journal Science. This magma chamber rests between 3 to 6 miles (5 to 10 km) beneath the park.

Estimates vary, but a magma chamber may need to reach about 50 percent melt before molten rock collects and forces its way out. "It doesn't look like at this point that the [Yellowstone] magma reservoir is ready for an eruption," said Farrell, co-author of the 2015 study in the journal Science.

How do researchers measure the magma? Seismic waves travel more slowly through hot or partially molten rock than they do through normal rock, so scientists can see where the magma is stored, and how much is there, by mapping out where seismic waves travel more slowly, Farrell said.

The magma storage region is not growing in size, either, at least for as long as scientists have monitored the park's underground. "It's always been this size, it's just we're getting better at seeing it," Farrell said.

Watch out for little eruptions

As with magma mapping, the science of forecasting volcanic eruptions is always improving. Most scientists think that magma buildup would be detectable for weeks, maybe years, preceding a major Yellowstone eruption. Warning signs would include distinctive earthquake swarms, gas emissions and rapid ground deformation.

Someone who knows about these warning signals might look at the park today and think, "Whoa, something weird is going on!" Yellowstone is a living volcano, and there are always small earthquakes causing tremors, and gas seeping from the ground. The volcano even breathes — the ground surface swells and sinks as gases and fluids move around the volcanic "plumbing" system beneath the park.

But the day-to-day shaking in the park does not portend doom. The Yellowstone Volcano Observatory has never seen warning signs of an impending eruption at the park, according to the USGS.

What are scientists looking for? For one, the distinctive earthquakes triggered by moving molten rock. Magma tunneling underground sets off seismic signals that are different from those generated by slipping fault lines. "We would see earthquakes moving in a pattern and getting shallower and shallower," Farrell said. To learn about the earthquake patterns to look for, revisit the 2014 eruption of Bardarbunga Volcano in Iceland. Both amateurs and experts "watched" Bardarbunga's magma rise underground by tracking earthquakes. The eventual surface breakthrough was almost immediately announced on Twitter and other social media. As with Iceland, all of Yellowstone's seismic data is publicly available through the U.S. Geological Survey's Yellowstone Volcano Observatory and the University of Utah.

"We would have a good idea that magma is moving up into the shallow depths," Farrell said. "The bottom line is, we don't know when or if it will erupt again, but we would have adequate warning."

(Becky Oskin / LIVESCIENCE Contributing Writer, May 2, 2016, https://www.livescience.com/20714-yellowstone-supervolcano-eruption.html?utm_source=notification)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΠΕΡΙΒΑΛΛΟΝ

7 Stunning Natural Wonders in Asia

Encompassing a wide variety of countries and cultures, Asia has no shortage of cities to visit and exciting foods to discover. But the continent is also packed with dramatic natural sights, some a little more remarkable than others. Whether you're looking for a short hike to conical hills, a surreal rainbow limestone landscape, or a multiday trek to sparkling Himalayan lakes, you'll find it in one of these natural wonders. Dive in and enjoy!

GOKYO LAKES TREK, NEPAL

A hike to Gokyo Ri will take you over 17,000 feet above the Himalaya. Above lakes and clouds you'll get a whole new perspective on its neighbor, Mount Everest.

A stunning alternative to the popular Everest Base Camp trek is summiting Gokyo Ri (17,576 feet) via the turquoise waters of the Gokyo Lakes. Fed by enormous Ngozumpa Glacier, the six lakes fan out over more than six miles of land, and make up the highest freshwater lake system in the world. The summit of Gokyo Ri affords vistas of towering Himalayan giants such as Lhotse, Nuptse, Makalu, Cho Oyu, and Gyachung Kang, weather permitting. Stellar Everest views are part of what makes this trek appealing—a view that comes without taxing the limited infrastructure at Everest Base Camp itself.

Getting There: Book a Gokyo Lakes trek with a tour company in Kathmandu, via a short flight to Lukla.

CHOCOLATE HILLS, THE PHILIPPINES

During the wet season the Chocolate Hills of Bohol, the Philippines, are vibrant and green. Visit when they dry out to see where they truly get their name.

In rainy season these conical hills are more green than chocolate, but once the rains stop the Chocolate Hills turn brown. Consisting of about 1,776 mounds jutting up from the island of Bohol, the hills are a national geological monument of the Philippines. Geologists theorize that karst rocks eroded in unison and formed the hills, leaving behind a landscape now covered in flora. Several local legends offer more colorful explanations. Among them: Two giants went to battle, hurling stones and sand back and forth until they were too tired to fight. Left in their wake? The perfectly formed Chocolate Hills.

Getting There: From Tagbilaran, Bohol's capital, take a tour to the hills, or DIY via a bus to Carmen, followed by a 10-minute walk from the main road.

MOUNT KELIMUTU, INDONESIA

While remote, Mount Kelimutu's lunar landscape and shimmering waters make it a worthwhile trek. Located on the island of Flores, Kelimutu's claim to fame is its three summit crater lakes, each with a different-hued pool. Geologists have studied the crater over time for its chameleonlike properties. Each lake has shifted from one color to another over the years as it comes into contact with mineral-rich underwater fumaroles. The surprise element of a Kelimutu visit is that you rarely know what colors will greet you when you summit the volcano.

Getting There: Mount Kelimutu is located on Flores; Ende is the closest city. A flight from western Flores (Labuhanbajo) to Ende is the easiest option. Bus travelers can get closer to the mountain by taking a bus to the smaller town of Moni.

ZHANGYE DANXIA LANDFORM, CHINA

The colorful striations of the Zhangye Danxia landform in Zhangye, China.

The term "Danxia landform" describes not only the mountains of the Zhangye Danxia Landform Geological Park near Zhangye, China, but also several other areas in China. Each was created over millions of years when the movement of tectonic plates and the weathering of sandstone created these magnificent vistas. The striation within the Danxia rocks results from the crumpling of limestone as the rocks compressed together over time. In 2010, UNESCO recognized six landforms as the China Danxia. The Zhangye Danxia landform is the biggest, covering more than 3,200 square feet. Several viewing platforms offer scenic glimpses of the surrounding rainbow rocks.

Getting There: Zhangye, in China's Gansu Province, is the nearest city. A taxi can be arranged from Zhangye to the park. Day tours are also possible via Zhangye.

HANG SON DOONG CAVE, VIETNAM

There is plenty to discover in Hang Son Doong cave in Phong Nha-Ke Bang National Park, Vietnam. The cave is one of the largest in the world and requires a licensed guide to explore.

Located within Phong Nha-Ke Bang National Park, Hang Son Doong is one of the world's largest, with its main cavern big enough to house a Boeing 747 plane. A wide, fast river that tunneled through the Earth over time formed Hang Son Doong, whose name translates from Vietnamese to "mountain river cave." Ho Khanh, who took refuge within it during a storm, discovered Son Doong in 1991. Lost again until 2009, the cave is now open to tourism. Proposed developments, including a cable car, have raised concerns with environmentalists. For now, only Oxalis Tours is licensed to guide tourists through Hang Son Doong.

Getting There: Oxalis offers multiday expeditions for $3,000 (U.S.). An alternative for those in the area is Thien Duong Cave (Paradise Cave) in the same national park. Buses run to Phong Na from Dong Hoi and from Hanoi.

BAN GIOC-DETIAN FALLS, VIETNAM-CHINA BORDER

This aerial footage offers a captivating look at the expansive falls that sit on the border of China and Vietnam.

Much like Niagara Falls, straddling the United States and Canada, Ban Gioc-Detian Falls sits on a border in Asia: that between Vietnam and China. Surrounded by karst rocks and green forest, the twin waterfalls tumble down in tiers to the Quay Son River below. While the waters' vertical drop is slight, the width of the cascades make for an impressive sight. Swimming is prohibited, but you can take small bamboo rafts to the very edge of the falls. During the hot rainy season from May to September, the Quay Son swells, widening the water flow considerably.

Getting There: On the Chinese side, the falls are three to four hours from the city of Nanning, with a daily bus leaving the Langdong bus station in the city. Day tours can also be arranged via Nanning. From the Vietnamese side, the falls are around 225 miles from Hanoi, and buses leave the My Dinh bus station for Cao Bang city. From there, a second bus will drop you off at the falls.

JIGOKU VALLEY, JAPAN

Colorful foliage surrounds Oyunuma Lake in Jigoku-Dani, Noboribetsu, Japan. The thermal hot springs are a popular stop for visitors in Shikotsu-Toya National Park.

Located on the island of Hokkaido, Jigoku Valley is part of the Shikotsu-Toya National Park near the town of Noboribetsu. The region is famous for its healing *onsen* thermal hot springs, experienced via spas at the city's hotels or outdoor mineral pools. A more sulfurous option is Hell Valley, the 24-acre geothermal crater left in the wake of Mount Kuttara's eruption thousands of years ago. The city has set up boardwalks around the valley, allowing people to meander through the many steam caves and geysers. Don't miss the Oyunuma Brook natural footbath, a healing spring within the park.

Getting There: Trains service the Noboribetsu station in town, a quick bus ride away from the hot springs area.

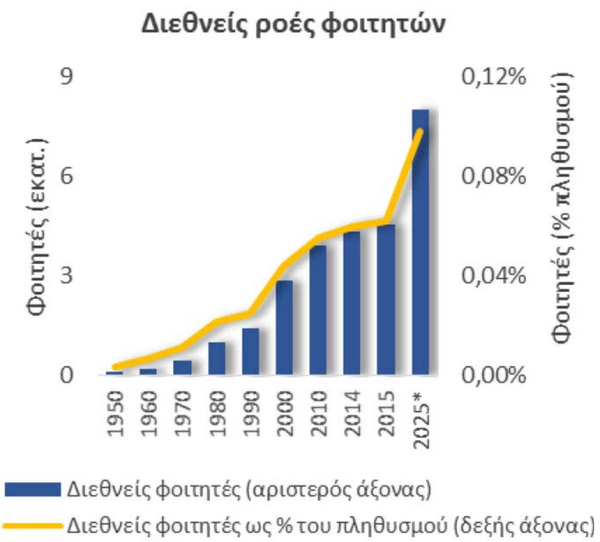
Jodi Ettenberg is a travel writer and the founder of Legal Nomads. You can follow her on Twitter and Instagram.

(Jodi Ettenberg / National Geographic, January 18, 2017, https://www.nationalgeographic.com/travel/top-10/natural-wonders-asia/?utm_source=NGdotcom-Travel&utm_medium=Email&utm_content=20180111_Travel_Newsletter_PM&utm_campaign=NGdotcom&utm_rd=1084349954)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

Η ανάδειξη της Ελλάδας σε Διεθνές Κέντρο Ανώτατης Εκπαίδευσης θα αναβαθμίσει την ποιότητα ανθρώπινου δυναμικού και θα δημιουργήσει σημαντικές συνέργειες με Καινοτόμες Επιχειρήσεις

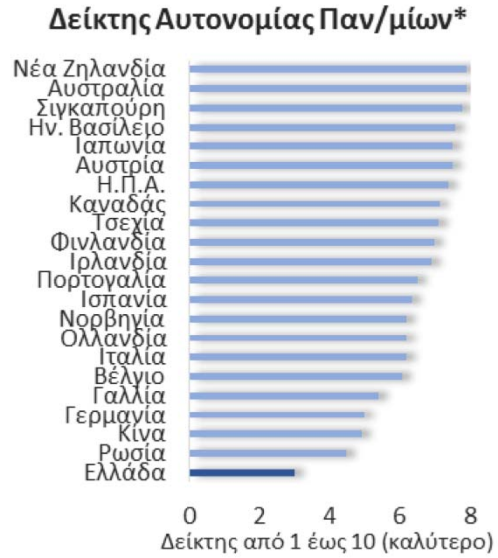
Αξιοποιώντας τη διεθνώς εκρηκτική αύξηση των φοιτητών που επιλέγουν να σπουδάσουν στο εξωτερικό, την ιστορικά αναγνωρισμένη υπεροχή της Ελληνικής Παιδείας και την ύπαρξη σημαντικής ακαδημαϊκής Διασποράς, η Ελλάδα μπορεί να αναδειχθεί σε διεθνές κέντρο ανώτατης εκπαίδευσης. Η νέα μελέτη που συνέταξε η Διεύθυνση Οικονομικής Ανάλυσης της Εθνικής Τράπεζας εστιάζει στον εντοπισμό των παραμέτρων – θεσμικών και μη – που προσδιορίζουν αυτή τη δυναμική και την αποτύπωση των πολιτικών που μπορούν να την ξεκλειδώσουν. Βασικό συμπέρασμα της ανάλυσης είναι, ότι πέρα από την άμεση εισροή πόρων από τους αλλοδαπούς φοιτητές, η αναβάθμιση του τομέα ανώτατης εκπαίδευσης θα μετασχηματίσει την Ελλάδα σε οικονομία έντασης γνώσης, αυξάνοντας σημαντικά το δυνητικό ρυθμό ανάπτυξής της (κατά 1-2 ποσοστιαίες μονάδες ετησίως την πρώτη δεκαετία έντονων μεταρρυθμίσεων και κατά περίπου ½ ποσοστιαίας μονάδας ετησίως μεσοπρόθεσμα). Συνεκτιμώντας τις συνέργειες αυτής της μεταρρύθμισης με ένα δεκτικό στην καινοτομία επιχειρηματικό τομέα, η συνολική επίδραση στο ΑΕΠ μπορεί να φτάσει τα €50 δις ετησίως σε ορίζοντα δεκαετίας.



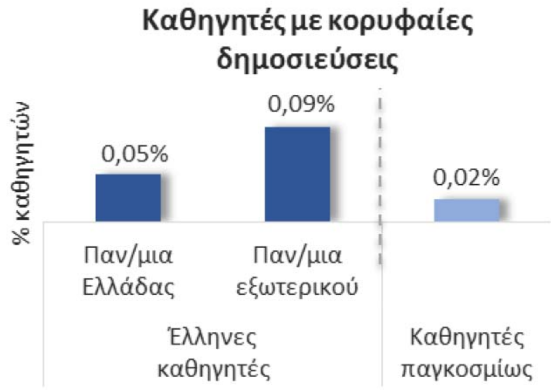
* εκτίμηση
Πηγή: Unesco, Εκτιμήσεις ΕΤΕ

Το διεθνές περιβάλλον είναι εξαιρετικά ευνοϊκό για το συγκεκριμένο εγχείρημα, καθώς οι ροές των διεθνών φοιτητών έχουν πενταπλασιαστεί κατά τις τελευταίες τέσσερις δεκαετίες (4,5 εκατ. φοιτητές το 2015 από 1,8 εκατ. το 1995 και 0,8 εκατ. το 1975). Ωστόσο, οι χώρες έχουν επωφεληθεί σε διαφορετικό βαθμό από αυτή τη θετική διεθνή συγκυρία ανάλογα με το επίπεδο ανταγωνιστικότητας των πανεπιστημίων τους. Στοχεύοντας στη μέτρηση της ακαδημαϊκής ανταγωνιστικότητας κάθε χώρας, κατασκευάσαμε το «Δείκτη Ανώτατης Εκπαίδευσης» λαμβάνοντας υπόψιν τους εξής παράγοντες:

- το επίπεδο αυτονομίας των πανεπιστημίων,
- την ποιότητα των καθηγητών (όπως μετράται από τις δημοσιεύσεις τους),
- το επίπεδο δαπανών για πανεπιστημιακή έρευνα (ως ποσοστό του ΑΕΠ), και
- τη γλώσσα κάθε χώρας (με την αγγλική ως πιο υποστηρικτική).



** βάσει έρευνας ΟΟΣΑ (2009)*
Πηγή: Martins et al, "The policy determinants of investment in tertiary education", OECD 2009, Ετιμήσεις ΕΤΕ

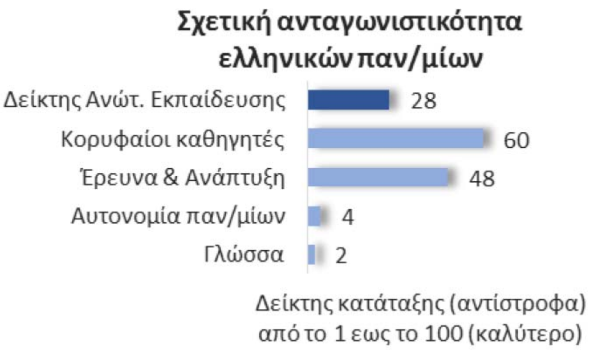


Πηγή: Thomson Reuters/Highly Cilted Researchers 2016, World bank, Εκτιμήσεις ΕΤΕ

Η χαμηλή θέση της Ελλάδας στο Δείκτη Ανώτατης Εκπαίδευσης (28/100) αντανακλάται στο μικρό μερίδιο της Ελλάδας στην προσέλκυση των διεθνών ροών φοιτητών (0,7%) – με την πλειοψηφία των ξένων φοιτητών να προσελκύονται είτε βάσει διμερών συμφωνιών (π.χ. από Κύπρο) είτε να είναι παιδιά μεταναστών (π.χ. από Αλβανία). Ωστόσο, ενώ η ανταγωνιστικότητα της Ελλάδας σε αυτόν τον τομέα είναι στην παρούσα φάση χαμηλή, η διεθνής θέση της χώρας θα μπορούσε να ενισχυθεί σημαντικά αξιοποιώντας και το συγκριτικό πλεονέκτημα της μεγάλης ακαδημαϊκής Διασποράς (με το 60% των Ελλήνων πανεπιστημιακών καθηγητών να απασχολούνται στο εξωτερικό, σε σχέση με έναν ευρωπαϊκό μέσο όρο της τάξης του 11%).

Βάσει των εκτιμήσεών μας, η Ελλάδα θα μπορούσε να προσελκύσει 110.000 ξένους φοιτητές (από 27.600 το 2015), εφαρμόζοντας τις παρακάτω πολιτικές:

- Εγκαθίδρυση συνεπούς και σταθερής εθνικής στρατηγικής για την ανώτατη εκπαίδευση με έμφαση στην αυτονομία των πανεπιστημίων (προσεγγίζοντας υψηλά επίπεδα αντίστοιχα του Ηνωμένου Βασιλείου και της Σιγκαπούρης), τη χρηματοδότηση βάσει αποτελεσμάτων και τις διεθνείς συνεργασίες.



Πηγή: World bank, Thomson Reuters, Eurostat, OECD,

- Νομοθέτηση πολιτικών και κινήτρων για προσέλκυση της ακαδημαϊκής Διασποράς, όπως έχει εφαρμόσει με επιτυχία η Κίνα. Σημειώνουμε ότι οι Έλληνες καθηγητές που απασχολούνται σε πανεπιστήμια εξωτερικού είναι υψηλής ποιότητας - με το ποσοστό αυτών με πολλές βιβλιογραφικές αναφορές (highly-cited) να είναι πενταπλάσιο του παγκόσμιου μέσου όρου.
- Στήριξη της δημιουργίας Κέντρων Αριστείας γύρω από τα ελληνικά πανεπιστήμια για ενδυνάμωση της σύνδεσής τους με τον επιχειρηματικό τομέα (με ταυτόχρονη ενίσχυση της ακαδημαϊκής έρευνας, με τις σχετικές δαπάνες να αυξάνονται στον ευρωπαϊκό μέσο όρο (0,5% του ΑΕΠ έναντι 0,3% σήμερα στην Ελλάδα). Αντίστοιχα Κέντρα Αριστείας έχουν αναπτυχθεί στη Γαλλία και στο Ισραήλ.

Η ανάδειξη της Ελλάδας σε διεθνές κέντρο ανώτατης εκπαίδευσης εκτιμάται ότι θα έχει πολλαπλά οφέλη για την ελληνική οικονομία. Σε πρώτο επίπεδο, η άμεση επίδραση από την προσέλκυση των ξένων φοιτητών (σε συνδυασμό με τον περιορισμό των εκροών Ελλήνων φοιτητών) θα προσελκύσει πόρους της τάξης των €1,8 δις ετησίως (κυρίως μέσω υψηλότερων εξαγωγών και χαμηλότερων εισαγωγών υπηρεσιών εκπαίδευσης). Σημειώνουμε ότι η τρέχουσα εκροή Ελλήνων φοιτητών σε πανεπιστήμια του εξωτερικού είναι από τις υψηλότερες στην ΕΕ (καλύπτοντας το 9% των Ελλήνων φοιτητών, έναντι ευρωπαϊκού μέσου όρου της τάξης του 3%).

Πηγές: UNESCO, Eurostat, Εκτιμήσεις ΕΤΕ

Ωστόσο, εκτός από το άμεσο αυτό αποτέλεσμα, η αναβάθμιση της ανώτατης εκπαίδευσης δύναται να μετασχηματίσει το μοντέλο ανάπτυξης της ελληνικής οικονομίας μέσω βελτίωσης της ποιότητας του ανθρώπινου δυναμικού της. Συγκεκριμένα, βάσει εκτιμήσεων από το «Υπόδειγμα Μακροπρόθεσμης Ανάπτυξης και Ανώτατης Εκπαίδευσης» της ΕΤΕ, οι προαναφερθείσες μεταρρυθμίσεις θα προσθέσουν στο ρυθμό ανάπτυξης του ελληνικού ΑΕΠ 1,1 ποσοστιαίες μονάδες ετησίως κατά την πρώτη δεκαετία έντονου μετασχηματισμού (αυξάνοντας έτσι το ΑΕΠ κατά περισσότερα από €20 δις ετησίως σε ορίζοντα δεκαετίας) και κατά 0,4 ποσοστιαίες μονάδες μεσοπρόθεσμα.

Πηγή: Εκτιμήσεις ΕΤΕ

Επιπλέον, σε περίπτωση που η ακαδημαϊκή αναβάθμιση συνδυαστεί με σταδιακή βελτίωση της ποιότητας του επιχειρηματικού περιβάλλοντος (όπως σχηματισμός clusters, είσοδος σε διεθνείς αλυσίδες αξίας και στρατηγικές branding), η δημιουργία ισχυρών συνεργιών με τον καινοτόμο επιχειρηματικό τομέα εκτιμάται ότι θα διπλασίαζε τις επιδράσεις στην ανάπτυξη της ελληνικής οικονομίας – προσθέτοντας στο ρυθμό ανάπτυξης 2,6 ποσοστιαίες μονάδες ετησίως κατά την πρώτη δεκαετία (αυξάνοντας έτσι το ΑΕΠ κατά περίπου €50 δις ετησίως σε ορίζοντα 10ετίας) και κατά περίπου 1 ποσοστιαία μονάδα μεσοπρόθεσμα. Σημειώνουμε ότι οι παραπάνω εκτιμήσεις υποεκτιμούν το συνολικό όφελος από την εκπαιδευτική αναβάθμιση, καθώς ο μετασχηματισμός της ελληνικής οικονομίας σε οικονομίας γνώσης δύναται να προσελκύσει επενδύσεις κεφαλαίου, αυξάνοντας έτσι περαιτέρω τους ρυθμούς ανάπτυξης του ελληνικού ΑΕΠ.

Η μελέτη για την ανώτατη εκπαίδευση μπορεί να ανευρεθεί στην ενότητα Κλαδικές Αναλύσεις του E.Spot (online περιοδικό της Εθνικής Τράπεζας) στην ακόλουθη ιστοσελίδα: https://www.nbg.gr/el/the-group/press-office/e-spot/reports/education

Αθήνα, 30 Μαΐου 2017

ΝΕΕΣ ΕΚΔΟΣΕΙΣ ΣΤΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΠΙΣΤΗΜΕΣ

Tall building foundation design

Harry G. Poulos

This book provides a comprehensive guide to the design of foundations for tall buildings.

After a general review of the characteristics of tall buildings, various foundation options are discussed followed by the general principles of foundation design as applied to tall buildings. Considerable attention is paid to the methods of assessment of the geotechnical design parameters, as this is a critical component of the design process. A detailed treatment is then given to foundation design for various conditions, including ultimate stability, serviceability, ground movements, dynamic loadings and seismic loadings. Basement wall design is also addressed. The last part of the book deals with pile load testing and foundation performance measurement, and finally, the description of a number of case histories.

A feature of the book is the emphasis it places on the various stages of foundation design: preliminary, detailed and final, and the presentation of a number of relevant methods of design associated with each stage.

Reviews

"This is a very valuable book, since it introduces a complex and not universally known problem and authoritatively suggests the proper approaches and methods of analysis to solve it."

-- *Carlo Viggiani, University of Napoli Federico II, Italy*

"This is a most comprehensive book on 'Tall Building Foundation Design', and I can think of no one better placed to write it than the author, Professor Harry Poulos. Although the title suggests the book only covers foundation design, that is far from the truth. The opening chapters provide an excellent overview of tall buildings, both historically and also in terms of different structural approaches. Later chapters include detailed consideration of design for dynamic conditions and seismic events, while the final chapter presents five detailed case histories in addition to an overview of measured settlements from tall buildings. The heart of the book addresses detailed design methods for different types of foundations for tall buildings, from both ultimate and serviceability points of view, but there are also chapters on diaphragm wall design for deep excavations, on relevant techniques of site investigation, on load testing of piles and on performance monitoring. So, just as Poulos' previous books, this book is essential reading for anyone involved in foundation design for significant structures, but there is much here that will appeal from a general interest perspective. I commend the author most highly on his energy in putting together a book of this breadth, and one which is extremely timely in view of the exponential increase in the number of buildings exceeding 300 m in height."

-- *Mark Randolph, University of Western Australia*

"It is a comprehensive and enjoyable read, taking the reader through a journey of discovery of what to design for, choices to be made, best practice methods to use, monitoring and testing during construction, as well as monitoring after construction. To top off a good story line, the book is rich on case studies and references to support a practitioner to make this book part of the essential arsenal of literature when design tall building foundations."

-- *Eduard Vorster, Aurecon, South Africa*

"All the design aspects are addressed (ULS, SLS, dynamic loading, earthquake loading, effects induced by ground movements), as well as control aspects like pile load testing and monitoring."

-- *Alessandro Mandolini, Campania University, Italy*

"This book is as comprehensive and thorough a book as I have seen on the subject of foundations for high-rise buildings. I think Dr. Poulos has largely achieved his goal of writing a book whose founding principles will stand the test of time."

-- *Alan Poeppel and George Leventis, Langan International, USA*

"It is a very well-written and instructive book. It is an extremely useful text for research and consulting structural and geotechnical engineers, and it can also be used as a reference book in graduate-level geotechnical engineering courses."

-- *Braja M. Das, Dean Emiritus, California State University*

(CRC Press, July 20, 2017)

Science for disaster risk management 2017

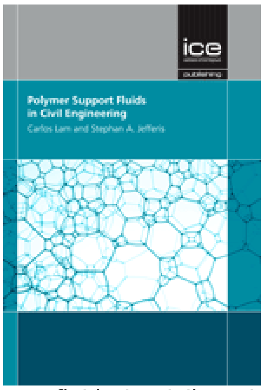
Knowing better and losing less - Study

The Disaster Risk Management Knowledge Centre has produced this flagship science report as a contribution to the Science and Technology Roadmap of the Sendai Framework for Disaster Risk Reduction. This report is the result of the multi-sectorial and multi-disciplinary networking process and represents the combined effort of more than two hundred experts. It will support the integration of science into informed decision making through synthesizing and translating evidence for disaster risk management and strengthening the science-policy and science-operation interface.

EU publications, Published: 2017-05-11

(https://publications.europa.eu/en/publication-detail/-/publication/4bc0e055-3712-11e7-a08e-01aa75ed71a1/language-en/format-PDF/source-40844781)

σ.ε. Ο συντονισμός των κεφαλαίων για σεισμούς, ηφαιστειακές εκρήξεις και tsunami έγινε από τον Διευθυντή Ερευνών του Γεωδυναμικού Ινστιτούτου του Εθνικού Αστεεροσκοπείου Αθηνών Γεράσιμο Παπαδόπουλο.



Polymer Support Fluids in Civil Engineering

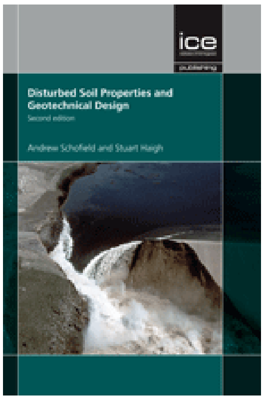
Carlos Lam and Stephan Jefferis

Polymer Support Fluids in Civil Engineering provides a detailed study of the use of polymer support fluids in civil engineering, covering all major aspects including fundamental material properties, laboratory and site testing, as well as case histories and specifications. This book includes all the information necessary to optimise the use of polymer support fluids and the performance of the resulting foundation elements.

The opening chapters describe the development of polymer fluid technology, including the various types of commercial polymer system currently available and the constraints on the use of bentonite support fluids. They are followed by chapters on site equipment and procedures, and laboratory and site techniques for assessing the physical and chemical properties of polymer fluids. Two chapters are then dedicated to detailed reviews of published case histories from around the world with analysis of successes, and importantly, possible reasons for failures that have occurred. The book concludes with a critical review of the specifications for the use of polymer fluids and a discussion of the rationale for the selection of the control parameters.

Written by two experts in this area, *Polymer Support Fluids in Civil Engineering* is the first book on the use of polymer support fluids in the construction industry. It will be an invaluable and authoritative reference for practitioners, researchers and advanced students working in geotechnical engineering.

(ICE Publishing, 24.11.2017)



Disturbed Soil Properties and Geotechnical Design, Second Edition

Andrew Schofield and Stuart Haigh

Disturbed Soil Properties and Geotechnical Design, Second edition describes the developments leading to the Original Cam Clay model, focusing on fundamentals of the shearing of soil. The first edition explained and illustrated fallacies in past work of engineering geologists, and laid groundwork for the understanding that should form the basis of modern geotechnical design.

With the changing environment, and the increasing size of construction projects, engineers now need a better understanding of ground behaviour to prevent future catastrophes such as the 1976 Teton Dam failure shown on the cover. The further additions in this book will help geotechnical engineers acquire this knowledge.

Disturbed Soil Properties and Geotechnical Design, Second edition:

• provides an outline of the energy-based Cam-clay approach that can predict geotechnical deformations

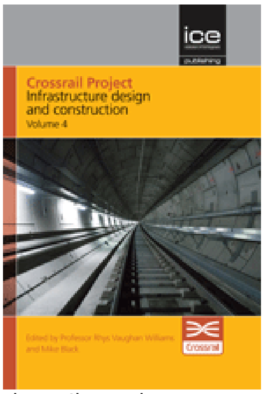
• illustrates further fallacies in commonly used c-φ Coulomb soil mechanics

• describes the use of centrifuge modelling in geotechnical design, based on examples from the last four decades

Once armed with the simple concepts of wet/weepy and dry/thirsty sides of the critical state line, readers will better understand if soil will tend to contract or dilate in drained shearing, and if pore pressures caused by undrained shearing will be positive or negative

Full of technical and personal insights, this is a rewarding book that forces the rethinking of modern geotechnical engineering. Much like the first edition, this book remains an invitation for the unconverted to re-examine the basic understanding of soil behaviour, and for the converted to ensure that the teaching, vocabulary and nomenclature used in describing strength models for soil, accurately reflect the underlying concepts.

(ICE Publishing, 22.11.2017)



Crossrail Project: Infrastructure Design and Construction - Volume 4

Crossrail, Rhys Vaughan Williams and Mike Black

The construction of the Crossrail project began at North Dock in Canary Wharf in May 2009. With the railway due to open in 2018, it is one of the largest single infrastructure investments undertaken in the UK to date. It consists of 21 kilometres of new twin-bore tunnels and 10 new world-class stations in central London connecting to upgraded lines providing new services to the east and west of the UK capital.

Crossrail Project: Infrastructure Design and Construction - Volume 4 contains a collection of 23 papers submitted to Crossrail's Technical Papers Competition. Contributions have come from consultants, contractors, suppliers and third-party stakeholders all of whom have been involved in the Crossrail project. The papers cover a variety of disciplines including health and safety, insulation materials, material corrosion, ground engineering and many more.

As part of the legacy of the Crossrail project, it is important for the organisation to share its experiences and best practices with the rest of the industry and to showcase the skills of the personnel involved and the successful delivery of each phase of works. This fourth volume continues Crossrail's dissemination of that experience.

Crossrail Project: Infrastructure Design and Construction – Volume 4 provides a valuable source of reference for current practices in design and construction of large-scale underground projects.

(ICE Publishing, 12.09.2017)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

www.geoengineer.org/geonews144.html

Κυκλοφόρησε το Τεύχος #144 του **Newsletter του Geoengineer.org** (Μαΐου 2017) με πολλές χρήσιμες πληροφορίες για όλα τα θέματα της γεωμηχανικής. Υπενθυμίζεται ότι το Newsletter εκδίδεται από τον συνάδελφο και μέλος της ΕΕΕΕΓΜ Δημήτρη Ζέκκο (secretariat@geoengineer.org).

Ενδεικτικά αναφέρονται:

- 10,000 homes could be damaged by earthquake-induced landslides in Wellington, NZ
- Link to mega bridge completed in Hong Kong
- In Memoriam: T. W. "Bill" Lambe (1920-2017)
- Dam collapse in Paraguay causes major flooding (video)
- Garbage dump collapse in Sri Lanka kills at least 28 people
- Mudslides in Colombia leave more than 200 dead (video)
- Slow-moving landslide discovered near the 2014 Oso landslide site in Washington

http://www.geoengineer.org/geonews144.html

☙ ❧

https://about.ita-aites.org/component/acymailing/mailid-160?key=S7uZSQ0N&subid=1894-74d7627ed3e51b67271afdd9255b5891&tmpl=component&Itemid=843

Κυκλοφόρησε το Τεύχος 63 του THE ITA@NEWS (Μαΐου 2017) με τα ακόλουθα περιεχόμενα:

- Message from Tarcisio CELESTINO, ITA President
- A Royal Opening
- The program for WTC 2017 is falling into place
- WTC training course
- ITAtech - The information disseminator of new technologies in tunnelling
- The panel of Judges for the ITA Awards 2017 has been released
- YMG Regional Event
- WG 14 has released its newsletter
- TAN advocates govt, private sector investment in underground infrastructures
- Seminar in Yangon
- Tunnelling Asia, Mumbai
- XIII International Conference " Underground Infrastructure of Urban areas 2017"
- "The 2017 International Conference on Tunnels and Underground Spaces (ICTUS17)"

☙ ❧

Κυκλοφόρησε το Τεύχος 26 του Newsletter του ITACET Foundation (Μαΐου 2017) με τα ακόλουθα περιεχόμενα:

- President's address
- Editorial
- Session reports
  - Principles of Tunnel Design
  - Planning, Construction and Operation of Common Utility Corridors
  - Mechanized tunnelling in soft soil
  - Mechanized Tunnelling: Challenging Case Histories
  - Health, Safety and Logistics in Tunnel Construction
  - Risk Management in Tunnelling
- Forthcoming sessions
- Other events in preparation
  - Risk Management in Tunnelling
  - Sustainable Underground Solutions for Transport
  - Rock bolting and shotcreting
- News from Foundation scholarship students
  - Senthilnath Govindaraju Thangavelu receives prestigious award
  - Rodrigo Winderholler graduates from the Politecnico di Torino
- The Foundation welcomes a new secretary and communications assistant
- The Foundation's Council Met In Paris On 31st March

ΕΚΤΕΛΕΣΤΙΚΗ ΕΠΙΤΡΟΠΗ ΕΕΕΕΓΜ (2015 – 2018)

ΕΕΕΕΓΜ

Τομέας Γεωτεχνικής
ΣΧΟΛΗ ΠΟΛΙΤΙΚΩΝ ΜΗΧΑΝΙΚΩΝ
ΕΘΝΙΚΟΥ ΜΕΤΣΟΒΙΟΥ ΠΟΛΥΤΕΧΝΕΙΟΥ
Πολυτεχνειούπολη Ζωγράφου
15780 ΖΩΓΡΑΦΟΥ

Τηλ. 210.7723434
Τοτ. 210.7723428
Ηλ-Δι. secretariat@hssmge.gr ,
geotech@central.ntua.gr
Ιστοσελίδα www.hssmge.org (υπό κατασκευή)

«ΤΑ ΝΕΑ ΤΗΣ ΕΕΕΕΓΜ» Εκδότης: Χρήστος Τσατσανίφος, τηλ. 210.6929484, τοτ. 210.6928137, ηλ-δι. ctsatsanifos@pangaea.gr, editor@hssmge.gr, info@pangaea.gr

«ΤΑ ΝΕΑ ΤΗΣ ΕΕΕΕΓΜ» «αναρτώνται» και στην ιστοσελίδα www.hssmge.gr