Αϊτή, σεισμός 20ης Ιανουαρίου 2010

Αρ. 153 – ΑΥΓΟΥΣΤΟΣ 2021

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ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ
& ΓΕΩΤΕΧΝΙΚΗΣ
ΜΗΧΑΝΙΚΗΣ

Τα Νέα της Ε Ε Ε Ε Γ Μ

153

Αϊτή 2021 Μ 7.2 επανάληψη του 2010

Στις 14 Αυγούστου η Αϊτή (το μικρό κράτος στην Καραϊβική, που μοιράζεται, με την Δομινικανή Δημοκρατία, το

(συνέχεια στην σελίδα 3)

Π Ε Ρ Ι Ε Χ Ο Μ Ε Ν Α

(συνέχεια από την 1η σελίδα)

νησί της Ισπανιόλα) δοκιμάστηκε για μια ακόμη φορά από σφοδρό σεισμό, μεγέθους Μ7.2, ίδιο σχεδόν με αυτό του σεισμού του 2010.

Ο σεισμός έπληξε το νοτιοδυτικό τμήμα της χώρας. Ο απολογισμός των θυμάτων στους ανέρχεται πλέον σε 2.207 νεκρούς, 344 αγνοούμενους και 12.268 τραυματίες.

Ο σεισμός σημειώθηκε στις 08:29 (τοπική ώρα· 15:29 ώρα Ελλάδας), 12km από την πόλη Saint-Louis-du-Sud, περίπου 160km από την πρωτεύουσα Port-au-Prince.

A magnitude 7.2 (M 7.2) earthquake struck Haiti on August 14, 2021, at 8:29 am local time (August 14, 2021 12:29 UTC)

The August 14, 2021 M 7.2 Haiti earthquake occurred as the result of oblique reverse motion along the Enriquillo-Plantain Garden fault zone, ~125 km west of the Haitian capital Port-au-Prince. The earthquake occurred at shallow depths on either a reverse fault striking west and dipping to the north with a component of left-lateral slip, or a fault striking southeast and dipping to the southwest with a component of right-lateral slip. At the location of the earthquake, the local plate boundary is dominated by left-lateral strike slip motion and compression. The plate boundary in this location accommodates eastward, left-lateral motion of the Caribbean plate relative to the North America plate. Within this context, the earthquake likely occurred on the east-west striking, north dipping fault plane with a component of left-lateral slip.

On January 12, 2010, an M 7.0 earthquake struck the same peninsula of Haiti and was located ~75 km east of the August 2021 earthquake. The 2010 earthquake caused substantial damage in the city of Port-au-Prince and the surrounding regions where damage from the earthquake and subsequent cascading hazards caused over 200,000 fatalities. The August 2021 earthquake likely occurred within the same fault system as the January 2010 earthquake; however, the 2010 earthquake occurred on a blind thrust fault and not directly on the main plate-boundary fault.

(https://earthquake.usgs.gov/earthquakes/eventpage/us6000f65h/executive)

Εκκλησίες, καταστήματα, σχολεία, νοσοκομεία, σπίτια υπέστησαν ζημιές ή κατέρρευσαν εντελώς κατά τη διάρκεια της πολύ ισχυρής δόνησης, παγιδεύοντας όσους βρίσκονταν στο εσωτερικό κάτω από τα συντρίμμια.

Το Ελληνικό Υπουργείο Εξωτερικών ανακοίνωσε ότι θα δωρίση σε Διεθνή Οργανισμό, που ήδη δραστηριοποιείται στην Αϊτή, το ποσό των 100.000 Ευρώ ως συνεισφορά στην αντιμετώπιση των ανθρωπιστικών αναγκών που προέκυψαν ύστερα από τον πρόσφατο σεισμό, καθώς και τον τυφώνα που ακολούθησε.

Με την συμβολική αυτή κίνηση, η Ελλάδα στέκεται σήμερα δίπλα στον δοκιμαζόμενο Αϊτινό λαό και δεν λησμονεί ότι η Αϊτή ήταν η πρώτη χώρα στον κόσμο που αναγνώρισε την Ελληνική Επανάσταση.

Ο Αϊτινός πρόεδρος Ζαν Πιερ Μπουαγέ ήταν ο μόνος που απάντησε θετικά στην επιστολή που είχε αποστείλει ο Αδαμάντιος Κοραής και οι άλλοι επιφανείς Έλληνες στην παγκόσμια κοινότητα. Ο Μπουαγιέ, με απαντητική επιστολή στις 15 Ιανουαρίου 1822, αναγνωρίζει το δικαίωμα των Ελλήνων για αυτοδιάθεση και μιλά με θερμά λόγια για την επανάσταση. Αποτελεί την πρώτη επίσημη αναγνώριση της ελληνικής επανάστασης και του ελληνικού κράτους: «**Με μεγάλο ενθουσιασμό μάθαμε ότι η Ελλάδα αναγκάστηκε τελικά να αρπάξει τα όπλα, για να αποκτήσει την ελευθερία της και τη θέση που της ανήκει ανάμεσα στα κράτη. Πολίτες, μεταφέρετε στους συμπατριώτες σας τις θερμότερες ευχές για απελευθέρωση, που σας στέλνει ο λαός της Αϊτής**», έγραφε μεταξύ άλλων.

Θεωρώ ότι είναι πολύ μικρή η βοήθεια αυτή προς τον δοκιμαζόμενο λαό της Αϊτής, λαμβάνοντας υπ' όψη και την αστοχία της επιτροπής εορτασμού των 200 χρόνων από την Ελληνική Επανάσταση να μην καλέση τον Πρόεδρο της Δημοκρατίας της Αϊτής. Η αποστολή μιας ομάδας της ΕΜΑΚ, μαζί με την οικονομική βοήθεια, θα ήταν μια μικρή ανταπόδοση στην συμπαράστασή τους. Δυστυχώς, όμως, ο σεισμός συνέπεσε με τις εξαιρετικά μεγάλες και καταστροφικές πυρκαϊές στην Ελλάδα, με αποτέλεσμα να «ξεχαστή» το γεγονός…

Global fatal landslide occurrence from 2004 to 2016

Melanie J. Froude and David N. Petley

Abstract

Landslides are a ubiquitous hazard in terrestrial environments with slopes, incurring human fatalities in urban settlements, along transport corridors and at sites of rural industry. Assessment of landslide risk requires high-quality landslide databases. Recently, global landslide databases have shown the extent to which landslides impact on society and identified areas most at risk. Previous global analysis has focused on rainfall-triggered landslides over short ~5-year observation periods. This paper presents spatiotemporal analysis of a global dataset of fatal non-seismic landslides, covering the period from January 2004 to December 2016. The data show that in total 55 997 people were killed in 4862 distinct landslide events. The spatial distribution of landslides is heterogeneous, with Asia representing the dominant geographical area. There are high levels of interannual variation in the occurrence of landslides. Although more active years coincide with recognised patterns of regional rainfall driven by climate anomalies, climate modes (such as El Niño–Southern Oscillation) cannot yet be related to landsliding, requiring a landslide dataset of 30+ years. Our analysis demonstrates that landslide occurrence triggered by human activity is increasing, in particular in relation to construction, illegal mining and hill cutting. This supports notions that human disturbance may be more detrimental to future landslide incidence than climate.

1 Introduction

Landslides are ubiquitous in any terrestrial environment with slopes, driven by tectonic (e.g. Bennett et al., 2016), climatic (e.g. Moreiras, 2005) and/or human (Petley et al., 2007) activities. Losses (fatalities, physical asset damage and economic costs) occur when people and their associated structures are exposed to landslides. The magnitude of the impact depends on the number of exposed elements and their associated vulnerabilities, the consequences of the impacts and the intensity of the landslide event (Glade and Crozier, 2005). A landslide event may include more than one slope failure triggered by the same phenomenon (e.g. a rainstorm). Interest in quantifying landslide risk has developed since the attempt by the International Association of Engineering Geology (IAEG) Commission on Landslides to compile a list of worldwide landslide events for the UNESCO annual summary of information on natural disasters in 1971 (UNESCO, 1973). Although incomplete, 5 years of records (1971–1975) recognised that landslides are a significant global hazard, with ca. 14 % of total casualties from natural hazards being attributed to slope failure (Varnes and IAEG Commission on Landslides, 1984). Since then, there has been a growing interest in landslide hazard and risk assessment (Wu et al., 2015).

Key elements of the assessment of landslide risk are coherent, high-quality landslide databases and inventories (van Westen et al., 2008; Van Den Eeckhaut and Hervás, 2012; Taylor et al., 2015). Inventories provide systematically compiled lists of landslide events that have occurred over a specific spatial scale (e.g. within a nation) within a set period of time or that result from a single, catastrophic triggering event (Hervás and Bobrowsky, 2009). Databases organise inventory information so that it is structured and searchable. Spatiotemporal analysis of global records of landslides have demonstrated the extent to which landslides impact on society and have identified geographical regions and countries most exposed (Petley, 2012). Several different global databases are actively maintained (e.g. the EM-DAT International Disaster Database, the NASA Global Landslide Catalogue and the Global Fatal Landslide Database (GFLD) on which this study is based), and their merits and limitations are discussed by Van Den Eeckhaut and Hervás (2012) and Kirschbaum et al. (2015). Global disaster databases are also maintained by risk reinsurers, but landslides are often included within broader categories (such as geophysical hazards or within weather-related hazards), and the majority of data are not freely available.

Relative to other natural disasters, the International Disaster Database (EM-DAT) suggests that landslides account for 4.9 % of all natural disaster events and 1.3 % of all natural hazard fatalities between 1990 and 2015; 54 % of these landslide events occurred in Asia (Guha-Sapir et al., 2018). However, the dedicated global landslide databases indicate that global multi-peril databases underestimate the impact of landslides on society. Petley (2012) showed that the EM-DAT database underestimated the number of fatal landslide events by ~2000 % and fatalities by 430 % between 2004 and 2010, whilst Kirschbaum et al. (2015) showed that the EM-DAT database underestimated the number of fatal landslide events by ~1400 % and fatalities by 331 % between 2007 and 2013. For the most part this under-reporting is associated with the perception of landslides as a secondary hazard, with the cause of death often being recorded in connection with the primary hazard (e.g. an earthquake rather than a coseismic landslide) rather than the actual cause of the loss.

Past studies on global landslide distribution have focused on rainfall-triggered events, recognising the importance of rainfall and climate in inhabited regions with steep slopes (Dowling and Santi, 2014; Kirschbaum et al., 2012, 2015). This paper not only provides a key update on the impact of landslides worldwide, extending Petley (2012) to include landslides from 2004 to 2016, the study also considers trends in landslides triggered by human activity, thereby adding to the discussion on climate versus human disturbance as current and future drivers of landslide incidence (Crozier, 2010).

2 The Global Fatal Landslide Database

The GFLD (formerly termed the Durham Fatal Landslide Database) has been compiled using systematic metadata search tools based in the English language that identify relevant reports of landslide activity (including all mass movements falling within the definition of Hungr et al., 2014) on a daily basis (Petley et al., 2005; Petley, 2010, 2012). In common with other hazard databases (Tschoegl et al., 2006; Taylor et al., 2015), mass media reports provide a first alert for fatal landslide occurrence and impact. Reports are corroborated and data updated by source triangulation using government and aid agency reports, academic papers and personal communications, as new information becomes available. The dataset has been consistently collected and managed since 2004, following a period of methodological development between 1 September 2002 and 31 December 2003 (Petley, 2012). The approach is differentiated from that of Kirschbaum et al. (2010, 2012, 2015) because (1) only landslides that cause loss of life are included and (2) all landslides are included, as opposed to only those triggered by rainfall. In addition, the GFLD has been compiled over a longer period. Although media reporting tends to be biased towards landslides with human casualties (Carrara et al., 2003), which is favourable for a database of this nature, it is recognised that the data collected are to some degree an underestimate of the number of fatal landslides and their associated losses. Landslides that occur in remote mountain regions, or that result in a small number of fatalities, are less likely to be reported than multi-fatality landslides and/or those that occur in urban centres (Petley, 2009). Reliability of reporting is also spatially variable, based on the robustness of regional communication networks, which are considered more consistent in developed nations (Petley, 2010; Kirschbaum et al., 2010), and in some cases political considerations (e.g. very few landslides are recorded in North Korea). The true number of fatalities may be slightly underestimated when victims die of landslide-derived injuries weeks to months following the event (Petley, 2012). Furthermore, solely non-English reporting of landslides will account for some missed reporting. Sepúlveda and Petley (2015) compared the GFLD with an independently compiled database based on original Spanish and Portuguese language reports for Latin America and found a difference of only 5 % of total records, generally associated with landslides with small numbers of fatalities. Combined, these effects may underestimate the true level of loss by up to 15 % (Petley, 2012); however, the methodology of collation of the GFLD is considered robust.

Since 2004, the database has been compiled to include the date of occurrence; the description of landslide location; an approximate latitude and longitude for that location; the country and geographical region (based on UN classifications, UNSD, 2018) in which the landslide occurred; the number of fatalities and injuries; and whether the event was triggered by rainfall, seismicity or another cause. Seismically triggered landslides in the database are excluded from analysis herein, because the catalogue of events is not considered complete (see Petley, 2012). These equate to 168 earthquake events and 3978 fatalities. In preparation of this paper, all landslide reports were reviewed to enhance the classification of the trigger event according to Table 1, using keyword searches in the original text describing the landslide. The description of the landslide event location may be specific to a section of road or village or give a more general location within an administrative division (such as a county or state). The locations of all landslide events are known within political country boundaries. To estimate the spatial precision of each landslide report, location descriptions were related to spatial databases of administrative boundaries (GADM, 2017), transport network maps (Google Maps, 2018; Open Street Map, 2018) and in some cases individual landslides could be identified from satellite imagery (Google Earth, 2018; Planet Team, 2017). For administrative units such as villages or states, polygon area from GADM (2017) provided the measurement of spatial precision. For a stretch of road, a polyline of the road length was created using transport network data (Open Street Map, 2018) and a 500 m buffer applied; the area of the buffer provided the precision estimate. The median spatial precision of entries is 681 km^2, with an interquartile range of 1 to 3477 km^2. The data are available to view at ESRI ArcGIS online at https://shefuni.maps.arcgis.com/apps/webappviewer/index.html?id=98462998953c4f1fbd7caaa166373f63 (Froude and Petley, 2018).

Table 1 Landslide trigger classification

Classification	Definition	Keyword search terms
Unknown	No trigger or obvious cause specified.	–
Rainfall	Rainfall raises pore pressure in slope materials triggering failure.	"rain", "sleet", "storm", "hurricane", "precipitation", "flood", "water", "torrent"
Earthquake	Strong ground motion associated with an earthquake weakens slope materials triggering failure (coseismic landslides).	"earthquake", "aftershock", "seismic", "tremor"
Illegal mining	Unregulated or informal mining of slope materials in designated quarry or mine, where permission to extract material has not been granted.	"illegal", "permit", "regulat", "close", "informal", "pick", "illicit", "abandoned", "traditional", "license", "ban", "mine", "quarry", "spoil", "pit", "excavat"
Illegal hill cutting	Hill cutting refers to the process of removing material from a hillslope for the purposes of altering its shape and/or to obtain slope material for use in construction, manufacture or farming. It is differentiated from mining because it occurs on slopes that are not within a designated site of mining or quarrying; instead hill cutting typically occurs on individual slopes on steep agricultural land or on man-made slopes such as those along transport routes. Hill cutting differs from construction because slope modification does not follow an engineering design to ensure slope stability. Hill cutting is assumed to be undertaken in an informal, unregulated manner (this is frequently noted in landslide reports).	"hillcut", "illegal", "permit", "regulat", "informal", "illicit", "traditional", "license", "ban", "excavat"
Legal mining	Regulated and/or permitted mining of slope materials in designated quarry or mine, where permission to extract material has been granted and operations are managed.	"legal", "permit", "regulat", "pick", "license", "mine", "quarry", "spoil", "pit", "excavat"
Mining (unknown)	Slope materials are extracted from a designated quarry or mine, but the report does not make it clear whether the extraction is permitted or not.	"quarry", "mine", "spoil", "pit", "excavat"
Construction	Permitted modification of a slope for the purposes of a construction project undertaken by professional labourers, following planning approval.	"excavat", "construction", "site", "road", "build", "dig", "labour"
Conflict and explosion	Landslide triggered by the detonation of an explosive device during military combat.	"bomb", "mine", "soldier", "army", "explode", "explosion", "war", "conflict"
Leaking pipe	Utility pipes carrying water have been damaged and leak water onto a slope surface or within the hillslope, compromising its stability.	"pipe", "leak", "burst"
Garbage collapse	Collapse of piles of municipal waste onto people, where stability of waste piles was disturbed by the passage of a person or persons.	"waste", "trash", "rubbish", "garbage", "dump", "pick"
Recreation	Triggered by passage of a person or persons walking or climbing over a hillslope for recreation.	"climb", "mountain", "expedition", "ascent", "trek"
Human action (unspecified)	Landslide report refers to a person or people present on a hillslope that collapses, without specifying the reason people occupied the slope or the landslide trigger.	"people", "person", "men", "women", "children", "occup"
Animal activity	Occupation of slope by animal triggering failure, either by weight and movement of animal on slope surface or by burrowing within the slope subsurface.	"animal", "burrow", "tunnel"
Fire	Naturally occurring or man-made fires, typically occurring in dry climates on vegetated terrain.	"fire"
Natural dam or riverbank collapse	Collapse of a riverbank or natural dam without an apparent trigger, but likely caused by pore pressures building over time to a critical threshold in response to water levels. Material typically fails into a body of water and often generates a flood wave.	"river", "bank", "dam", "earth", "flood", "wave", "collapse"
Freezing	Heavy snowfall and expansion of water in hillslopes due to freezing, acting solely or together to destabilise the slope.	"snow", "extreme", "freeze", "ice", "cold"
Freeze–thaw (temperature change cold to hot), snowmelt	Failure of slope materials in response to temperature rise, including landslides triggered by the melting of snow or permafrost (in a non-volcanic setting).	"snow", "melt", "permafrost", "spring", "temperature"
Volcanic eruption	Landslides (and mudflows) occurring in a volcanic environment triggered by volcanic activity such as explosions and volcano-tectonic seismicity. This does not include events in active volcanic environments triggered by rainfall.	"volcan", "seismic", "activity", "eruption"
Marine erosion	Triggered by sea erosion (only) repeat wave impact.	"coast", "sea", "erode"

3 Global fatal landslide occurrence, 2004 to 2016

The total number of fatal landslide events recorded worldwide, excluding those triggered by earthquakes, over the 12 calendar years between 2004 and 2016 (inclusive) was 4862. The majority of events (95 %) involved a single slope failure. The spatial distribution of landslides (Fig. 1a and c) is clearly heterogeneous, with high areas of incidence in

- Central America between Costa Rica and the South of Mexico;
- the Caribbean islands;
- South America, along the Andes mountain range from Venezuela to Bolivia and to a lesser extent Chile, with another cluster of events on the east coast of Brazil around the states of São Paolo and Rio de Janeiro;
- East Africa, around the borders between Tanzania, Rwanda, Burundi, Kenya, Uganda and Democratic Republic of the Congo;
- Asia (the site of the highest number of events; 75 % of landslides), with substantial numbers of landslides along the Himalayan Arc, in states across India and southeastern China, in the neighbouring countries of Laos, Bangladesh and Myanmar, and southwards on islands that form Indonesia and the Philippines;
- Turkey, Iran and the European Alps.

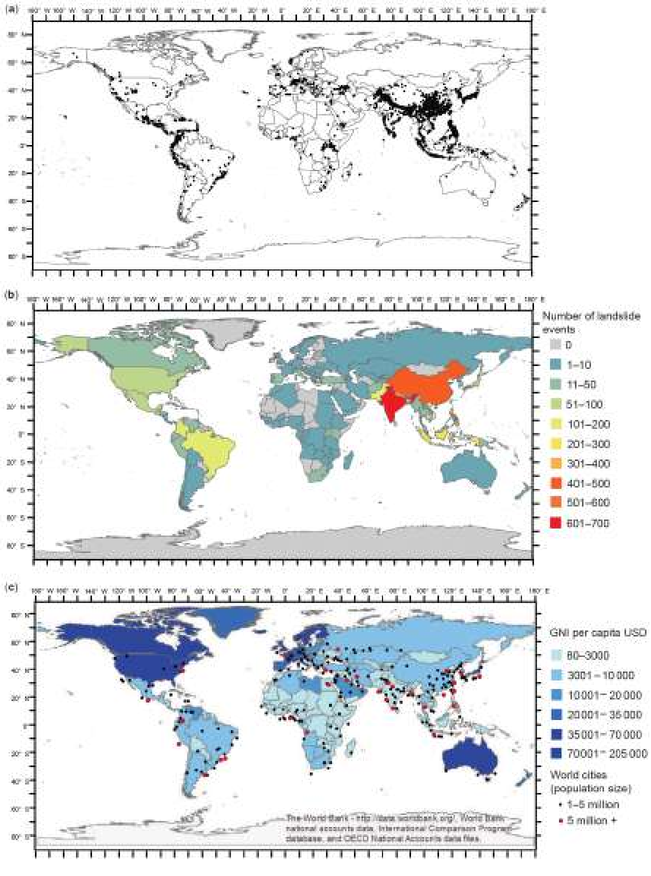

Figure 1(a) The location of non-seismically triggered fatal landslide events from 2004 to 2016. Individual landslide events shown by a black dot. **(b)** Number of non-seismically triggered fatal landslide events from 2004 to 2016 by country. **(c)** The gross national income per capita (USD) by country (World Bank, 2018a), and the location of major urban centres globally (ESRI, 2018).

Fatal landslide events cluster around cities (Fig. 1c) and occur most frequently in countries with lower gross national income (GNI in Fig. 1c) at locations known to be susceptible to landslides, based on the analysis of physical characteristics of the environment (see Hong et al., 2007; Stanley and Kirschbaum, 2017). Textual analysis of landslide reports shows many events occurred in mines or quarries (423 landslides), and 568 landslides in the dataset occurred on roads. Relative poverty is also emphasised in reporting: the term "slum" is explicitly used to describe the impacted community 29 times, while broader terms to indicate relative poverty are used 267 times within landslide reports. These observations support previous research that fatal landslides are most prevalent in densely occupied urban centres (Alexander, 1989; Anderson, 1992; Petley, 2009), along roads (Hearn, 2011; Lee et al., 2018) and at sites rich in natural resources (Zou et al., 2018). In common with other natural hazards, the poor are disproportionately affected by landslides (Hallegatte et al., 2016).

Figure 2 shows landslide occurrence in pentads, smoothed with a 25-day (i.e. five pentad) moving average. The most landslide events in a single pentad was 48, in early October 2009; of these 45 were triggered in a single day (8 October 2009) by Typhoon Parma in the Philippines. Rainfall is the leading trigger of landslides. The majority of non-seismic fatal landslide events (2004–2016) in the database were triggered by rainfall (79 %). Figure 3a shows landslide events triggered by rainfall in pentads, compared with the complete non-seismic landslide event dataset. The data series are strongly correlated (R of 0.933, p value of 0), indicating that rainfall-triggered landslides explain 93 % of the variance of the complete dataset. Figure 3b shows landslide events that were not triggered by rainfall and where the trigger is known (e.g. mining). We term these events "non-seismic non-rainfall triggered" (NSNR) landslides herein. These landslide events constitute 16 % of the complete dataset and present a different pattern through time when compared with rainfall-triggered landslide events. There is a notable increase in the number of landslide events with NSNR triggers from about 2006, which we ascribe to improved event capture.

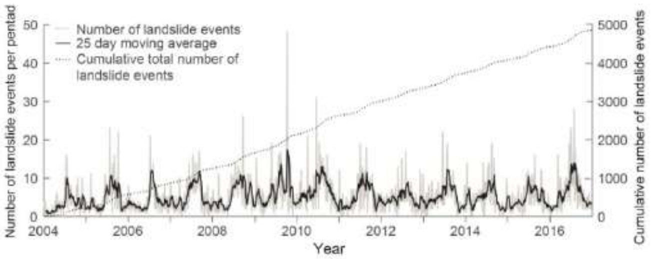

Figure 2 The occurrence of non-seismically triggered landslide events from 2004 to 2016, and cumulative total of recorded events. The data are arranged by pentads (5-day bins), starting on 1 January each year; thus the first pentad includes records for 1–5 January, and there are a total 73 pentads. A simple 25-day moving average is shown.

The rainfall-triggered landslide data in Fig. 3a (and the complete landslide series in Fig. 2) contain a strong seasonal pattern of landslide occurrence through the annual cycle, as noted by Petley (2012). Autocorrelation measures the linear relationship between lagged values of a time series. The autocorrelation of the rainfall-triggered pentad landslides series (Supplement Fig. S1) shows the correlation coefficient between the original series and a lagged version of the series, where the series lags between 1 and 948 pentads (5 days to ~ 13 years). The autocorrelation oscillates around 73.5 lags (pentads), equating to 1 calendar year. This pattern is indicative of annual seasonality in the data. Conversely, the autocorrelation of the NSNR landslides pentad series (Fig. S2) does not contain this pattern and the correlation coefficients are generally weak. This indicates that there is no seasonal pattern in the NSNR landslide series, which is to be expected in events that are not triggered by meteorological processes.

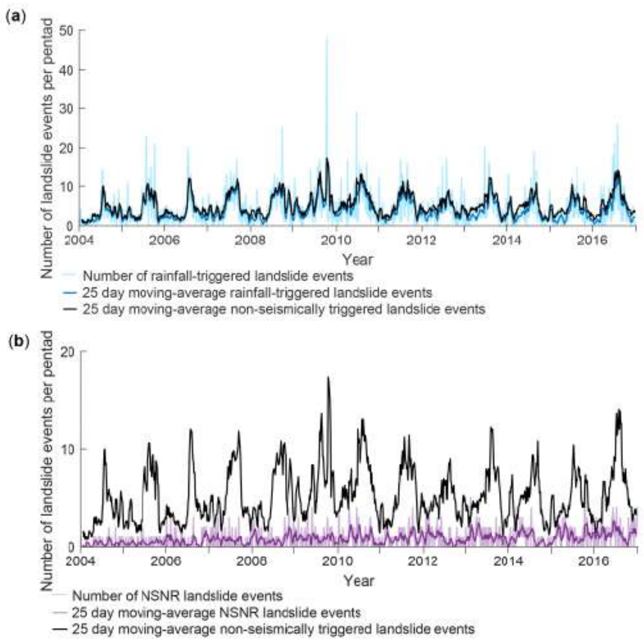

Figure 3(a) The occurrence of rainfall-triggered landslide events from 2004 to 2016 (blue). The data are arranged by pentads (5-day bins), starting on 1 January each year. A simple 25-day moving average is shown. The 25-day moving average for all non-seismically triggered landslide events is shown in black. **(b)** The occurrence of NSNR landslide events from 2004 to 2016 (purple). The data are arranged by pentads (5-day bins), starting on 1 January each year. A simple 25-day moving average is shown. The 25-day moving average for all non-seismically triggered landslide events is shown in black.

3.1 Seasonality

Landslide event occurrence peaks in the northern hemispheric summer, and there is notable interannual variation, in both the size and shape of the annual cycle. Seasonality in the global series (Figs. 2 and 3a) is associated with the annual cycle of rainfall-triggered landslides in South, Southeast and East Asia, and South and Central America (Fig. 4). Combined, these geographical regions contain 88 % of all rainfall-triggered landslide events and account for 96 % of variance in the global seasonal cycle (Table B1 in the Appendix). There is a correlation between the mean monthly rainfall (data from GPCC, 2018; Xie et al., 2013) and landslide series, for four of five regions (Fig. 5 and Table 2), reflecting the triggering effect of seasonal rainfall. However, the strength of relationship between seasonal patterns of rainfall and the seasonal pattern of landslide events is variable between regions. The pattern is strongest in East Asia and South Asia. This corroborates the results of Petley (2012), who identified the strong relationship between landslide occurrence and seasonal rainfall from a shorter period of data (2004 to 2009).

Table 2 Spearman's rank correlation between mean daily rainfall and mean daily landslides by month (see Fig. 5).

Region	Correlation coefficient	*P* value
Central America	0.8153	0.0012
South America	0.8062	0.0015
Southeast Asia	0.17	0.5974
South Asia	0.996	0
East Asia	0.9701	0

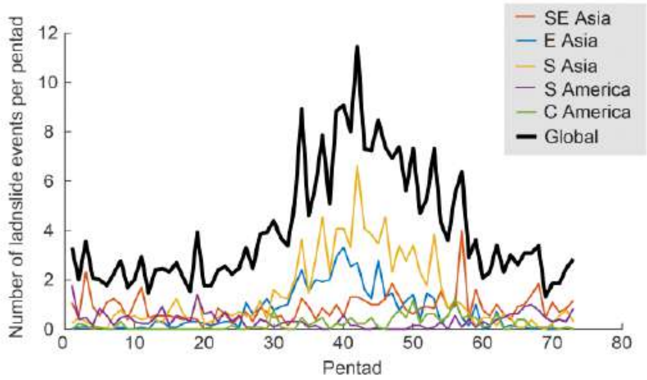

Figure 4 Mean number of landslides per pentad through the annual cycle for all rainfall-triggered landslides, by geographical region. The 20th pentad is the 6–10 April, the 40th pentad is 15–19 July and the 60th pentad is 23–27 October.

Seasonal rainfall in East and South Asia is associated with the onset and withdrawal of the Asian monsoon (e.g. Webster, et al., 1998), delivered by the seasonal reversing of winds to flow from ocean to land in the summer months, resulting in the majority of annual rainfall occurring between June and September (Turner and Annamalai, 2012). In South Asia, landslide incidence increases in Nepal, India, Bangladesh, Bhutan and northern Pakistan during the summer monsoon. India and Nepal contribute 16 and 10 % respectively of all rainfall-triggered landslide events in the global dataset; of these 77 and 93 % occurred during the summer monsoon, meaning 21 % of all rainfall-triggered landslide events globally were triggered by seasonal monsoon rainfall in India and Nepal. In East Asia, tropical cyclones extend the length of the rainfall season: 109 landslide events were triggered by typhoons between April and October in China, Japan and South Korea, representing 16 % of rainfall-triggered landslide events in East Asia and 3 % of global rainfall-triggered landslide events. The East Asia landslide record is dominated by events in China (81 %, 503 landslides), of which 409 landslide events were triggered during the summer monsoon rainfall season. China alone contributes 15 % of all global rainfall-triggered landslide events, although the pattern is heterogeneous.

Although the seasonal landslide series for Central and South America do not explain much variance in the global seasonal landslide cycle (because of the comparatively low number of landslides), there is strong correlation between patterns of landslides in the region and patterns of rainfall (Table 2). Central America and parts of the Caribbean experience a summer rainy season between May and October, associated with the position of the Intertropical Convergence Zone (ITCZ; Garcia et al., 2009). The season is bimodal, with peaks in rainfall on either side of a midsummer drought between late June and August (Magaña et al., 1999). The season is enhanced by the Atlantic basin hurricane season from 1 June to 30 November (NOAA, 2018a). The pattern of landslides reflects these rainfall drivers.

South America spans ~70° of latitude leading to local variability in climate (Sepúlveda and Petley, 2015). The peak annual rainfall for the continent as a whole occurs during the period from December through February, delivered by the South American Monsoon System, which is driven by the position of the ITCZ to the south of the Equator (Garcia et al., 2009). However, in parts of southeastern Brazil, where there is a prevalence for fatal landslides (Fig. 1), the rainy season extends into March (Rao and Hada, 1990). In northern Peru, rainfall peaks between April and June in the west and is bimodal in the east, with peaks in April and December (Espinoza Villar et al., 2009). Colombia's meteorology is particularly complex due to the convergence of the Equatorial Mid-tropospheric Easterly Jet and the Choco Jet; the resulting rainfall distribution is bimodal, with peaks in April–June and August–September, depending on precise location and the choice of rainfall data and model (Sierra et al., 2015). Most rainfall-triggered fatal landslide events in South America occur in Brazil (37 %) and Colombia (32 %), most notably in southeastern Brazil and central Colombia, and this is evident in the distribution of annual rainfall and landslide occurrence (Fig. 5d).

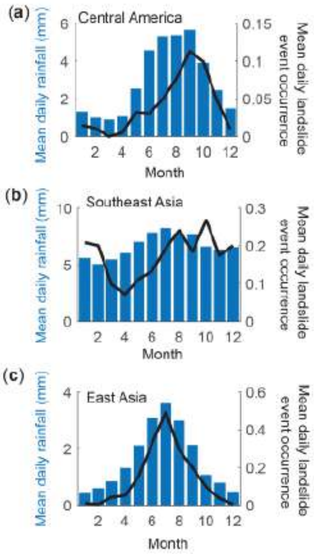

Figure 5 Mean daily rainfall (in millimetres) by month between 2004 and 2016, summarised by geographical subregion (blue bars). Global Precipitation Climatology Centre data (Xie et al., 2013; GPCC, 2018) were processed in ESRI ArcMap and MATLAB. Mean daily rainfall-triggered landslide event occurrence by month between 2004 and 2016 (black line). Daily values are used to overcome the difference in month length.

The weak relationship between rainfall and landslides in Southeast Asia reflects the complex weather systems operating in the region. Most landslide events occurred in the Philippines (46 %) and Indonesia (32 %). Typhoons caused 22 % of rainfall-triggered landslide events in the region, and 5 % globally; most typhoon-triggered landslide events occurred in July through October (75 %), in line with the main tropical cyclone season. In the Philippines, 42 % of rainfall-triggered landslide events were caused by typhoons, whilst the equivalent value for Vietnam was 22 %, although of a much lower total. The pattern of monsoon rainfall in Indonesia and the Philippines varies by geographical location. In the west of the Philippines, summer monsoon occurs between June and October, while in the east the winter monsoon occurs between October and March (Kubota et al., 2017). This pattern is evident in the distribution of rainfall-triggered landslides in the Philippines (Fig. 1a). The onset and termination of the monsoon in Indonesia varies from September to June in northern Sumatra and late November to late May in eastern Java (Naylor et al., 2007). Consequently, 72 % of rainfall-triggered landslide events occur between November and April, when the majority of Indonesia is experiencing monsoon rainfall. The peak in landslide activity relative to rainfall in August to October in Southeast Asia (Fig. 5b) is mainly due to the localised typhoon rainfall not captured in the regional rainfall average.

3.2 Medium-term trend in landslide occurrence

There was a general increase in recorded landslide occurrence between 2004 and March 2010, followed by a general decrease in landslide occurrence through April 2015, after which landslide incidence has generally increased (Fig. 6a). Petley (2012) identified improvements in the reporting of single-fatality landslides as contributing to the general increase in events in the fatal landslide record from 2004 to 2010. The number of fatalities resulting from non-seismic landslide events between 2004 and 2016 was 55 997. Figure 6b shows that the pentad series of fatality is very noisy; the data do not contain an increasing or decreasing trend, nor are there distinguishable medium-term peaks in the data. Very few landslide events generated more than 1000 fatalities (0.1 %), and only one landslide resulted in more than 5000 fatalities. This was the Kedarnath landslide in June 2013 in Uttarakhand state, India, which was caused by extreme meteorological conditions that generated flooding and two large landslides in a mountainous area occupied by thousands of religious pilgrims (Allen et al., 2016).

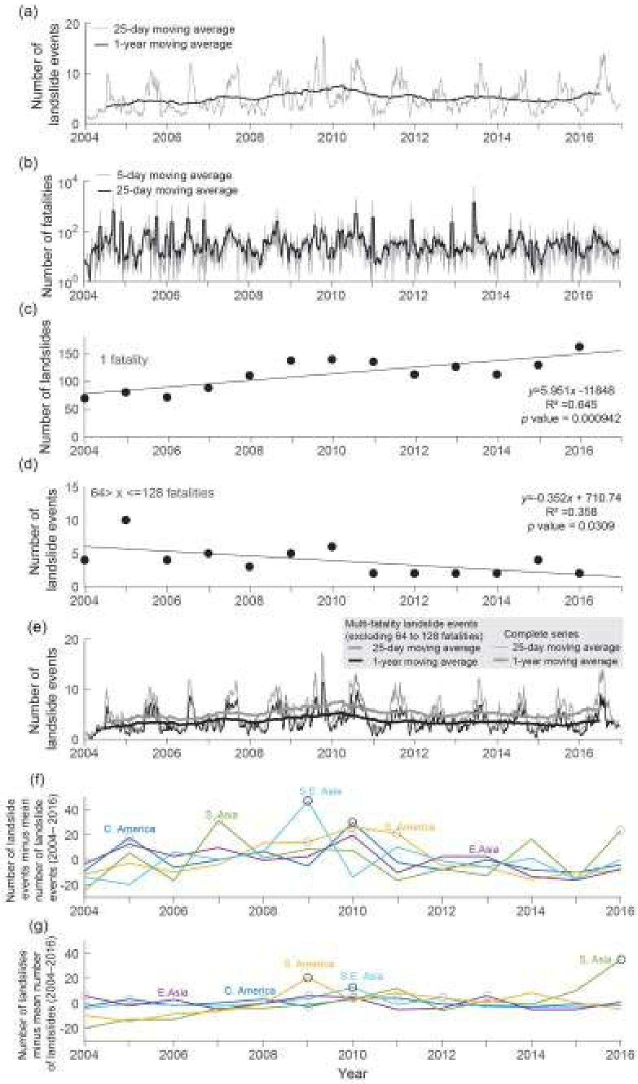

Figure 6(a) The occurrence of non-seismically triggered landslide events from 2004 to 2016: 25-day and 1-year moving average (see also Fig. 2). **(b)** The number of fatalities from non-seismically triggered landslide events from 2004 to 2016 by pentad with 25-day moving average. **(c)** Number of single-fatality landslides 2004 to 2016. **(d)** Number of landslide events incurring 64 to 128 fatalities per event from 2004 to 2016. **(e)** Comparison of the complete landslide series (Fig. 6a) and multi-fatality landslide series (excluding the 64- to 128-fatality class). **(f)** Anomalies in landslide event occurrence by year by geographical region (multi-fatality events). **(g)** Anomalies in landslide occurrence by year, by geographical region (single-fatality events). Values greater than 1 standard deviation from the mean are shown by a grey circle. Values greater than 2 standard deviations from the mean are shown by a black circle.

Landslide events by the number of fatalities are grouped by the infinite series (1, 2, 4, 8, 16 …). There is a significant increasing trend in single-fatality landslides (Fig. 6c); 29 % of landslides were single-fatality events. There is also a weaker decreasing trend in landslide events resulting in 64 to 128 fatalities (Fig. 6d); 1 % of landslide events were in this group. No other grouping contained a significant trend with time. Both the single-fatality and 64- to 128-fatality series are above the regression line in 2010 (Fig. 6c and d). Removing these two groups from the global series (Fig. 6e), it is evident that single-fatality events enhanced the peak around 2010 and in 2016.

By year, different geographical regions experience above or below average landslide activity (multi-fatality landslide events, Fig. 6f; single-fatality landslides, Fig. 6g). In 2005, 2009, 2010 and 2011, several regions experienced greater than average landslide occurrence simultaneously (Fig. 6f and g). The high impact of landslides globally in 2010 has been discussed by previous authors (Kirschbaum et al., 2012, 2015; Petley, 2012; Sepúlveda and Petley, 2015). The geographical pattern of rainfall-triggered landslide events in 2009 and 2010 reflects the occurrence of a moderate El Niño in 2009 and a moderate La Niña in 2010 (NOAA, 2018b).

In Central America, Kirschbaum et al. (2012) showed that rainfall was significantly above average in the summer months in 2010, particularly in September. This increase was linked to the known impacts of La Niña events on tropical cyclone frequency and track (e.g. Elsner et al., 1999; Curtis et al., 2007). By number, 2010 was the year in which the most landslides (17 events, compared with an average 6 events per year), were directly associated with tropical cyclones in reports or related to storm tracks (based on NOAA, 2018c). Although these landslide events only equate to 35 % of all rainfall-triggered landslide events within 2010, the remaining 65 % of events, not triggered by a tropical cyclone all occurred during the hurricane season (May to November), are likely due to unsettled weather associated with warm sea surface temperatures (SSTs) in the region. Central America receives tropical cyclones from the Atlantic basin and the North Pacific basin (NOAA, 2018c). Storms from the Atlantic basin may make landfall along the eastern coastline of Central America and travel inland, occasionally retaining enough energy to cross over into the Pacific. Storms that have crossed over basins or new storms, which have formed in the northeast Pacific basin, may make landfall on the western coast of Central America. Not only was the frequency of landfalling tropical storms and hurricanes elevated from both basins in 2010, but the track of these storms intercepted populated areas in steep terrain (NOAA, 2018c). The majority of rainfall-triggered landslide events in Central America in 2010 were in Mexico and Guatemala (43 and 37 % respectively). In Guatemala, eight landslide events were triggered by tropical storm Agatha in late May 2010, causing 182 fatalities. Four landslide events were associated with Hurricane Alex, which travelled up the east coast of Guatemala, Honduras and then inland to Mexico in late June–July 2010. Hurricane Karl then made landfall on the east coast of Mexico in September: two landslide events are associated with this storm (killing 12), but a succession of fatal landslides in the states of Oaxaca, Chiapis and Puebla, through which the hurricane passed, was noted in the weeks following the storm.

Sepúlveda and Petley (2015) observed a weak correlation between La Niña conditions in late 2010–2011 and heightened landslide activity in Colombia and Venezuela. Considering a longer time series (2004 to 2016), this study identifies above average landslide activity in several nations in South America in 2009 and 2011. In Brazil, 54 % of all rainfall-triggered events occurred between 2009 and 2011. Activity peaked in December 2009 to April 2010 (El Niño) and January 2011 (La Niña), corresponding with the seasonal El Niño–Southern Oscillation (ENSO) rainfall patterns observed by Grimm and Tedeschi (2009). The number of landslide events in Venezuela and Colombia between 2009 and 2011 peaked in November 2010, associated with positive rainfall anomalies during the austral summer La Niña (Tedeschi et al., 2013).

The majority of landslide events in East Asia occur in China (83 %); in 2010, 87 % of all rainfall-triggered events were located in China, and rainfall-triggered landslide occurrence (67 landslide events) was above the mean (45 landslide events). From a shorter period of observation, Kirschbaum et al. (2012) identified a high incidence of rainfall-triggered landslides (fatal and non-fatal) in central eastern China in 2010, particularly in July and August, corresponding with a peak in rainfall. Rainfall-triggered landslides were above average for most months in 2010 in China, but the period of May to September was very active (57 landslide events compared with an average 38). The East Asian subtropical summer monsoon (a component of the East Asian monsoon) has a significant effect on seasonal variations in rainfall across China (He and Liu, 2016), and rainfall patterns alter in response to ENSO conditions (Yang and Lau, 2004; He et al., 2007; Zhou et al., 2014).

In China in 2010 there were fewer than average landslide events triggered by tropical cyclones from the northwest Pacific basin. There was low typhoon activity due to the rapid transition from the 2009–2010 El Niño to the 2010–2011 La Niña, which altered airflows in the northwest Pacific basin (Kim et al., 2012). Conversely, in the Philippine domain, tropical cyclone occurrence was above average in July to December 2009 (Corporal-Lodangco et al., 2015). During the northern hemispheric summer months of an El Niño, the genesis location of tropical cyclones shifts eastwards (Chan, 1985, 2000; Chia and Ropelewski, 2002). In these conditions, cyclones travel further before they may make landfall, enabling them to strengthen (Camargo and Sobel, 2005), and there is a tendency for more storms to affect the northern-central Philippines (Lyon and Camargo, 2009). In 2009, 67 % of rainfall-triggered landslide events in the Philippines were associated with tropical cyclones: 60 landslide events compared with an average 12 triggered by tropical cyclones. As noted previously, many of these were triggered on the same day (8 October 2009) by Typhoon Parma.

Although the peak in landslides in Southeast Asia in 2009 is dominated by typhoon-triggered landslides in the Philippines, there was an increase in landslides in Indonesia (33 landslide events compared with an average of 24 per year); of these 24 events were triggered by rainfall, 8 by mining and one trigger was not known. Rainfall-triggered landslide events were very slightly above average in Indonesia in 2009 but it was the events triggered by human activity that contributed most to the anomalous landsliding in Indonesia. These landslides are discussed in the next section.

Between 2004 and 2016, four El Niño events occurred: weak El Niño (2004–2005, 2006–2007), strong El Niño (2009–2010) and very strong El Niño (2014/2016; NOAA, 2018b). Weak La Niña was observed in 2005–2006, 2008–2009 and 2016, and strong La Niña occurred in 2007–2008 and 2010–2011 (NOAA, 2018b). There does not appear to be a consistent relationship between ENSO phase and the regional distribution of landslides, although elevated regional rainfall (and thus landslides) has been associated with ENSO SST anomalies. The peak in landslide events in Central America in 2005 is composed predominantly of tropical storm and hurricane-triggered landslides in El Salvador, Mexico, Guatemala and Honduras. The 2005 North Atlantic hurricane season was the most active since records began in 1851, driven by high SSTs in the tropical North Atlantic (10–20° N) linked with global warming and the 2004/2005 El Niño (Trenberth and Shea, 2006). Landslide events were also above average in 2005 in East Asia: most events occurring in China, triggered by monsoon rainfall. In South Asia, landslide events peaked in 2007, 2014 and 2016, the majority associated with monsoon rainfall in Bangladesh, India, Nepal and Pakistan. Variability in rainfall from the South Asian monsoon is related to the interaction between SSTs in the Indian Ocean Dipole and ENSO (e.g. Ashok and Saji, 2007; Lu et al., 2017).

The complexity of climate systems means it is not possible to draw conclusions on the relationship between climate mode and landslide occurrence from this 13-year global dataset. However, longer local records show promise at unpicking the impact of climate cycles on landslides.

3.3 NSNR landslide triggers

Of the 4862 non-seismic landslide events in the complete database, 770 (16 %) were generated by a NSNR trigger and resulted in a total of 3725 fatalities (Fig. 7). The majority of landslides were triggered by mining (232 multi-fatality landslide events, 67 single-fatality landslides), construction (170 multi-fatality landslide events, 140 single-fatality landslides) or illegal hill cutting (60 multi-fatality landslide events, 27 single-fatality landslides); the majority of fatalities in all cases were people at work (90, 76 and 84 % respectively). Globally there is a statistically significant increase in events by these three triggers (Fig. 8a, b and c); multi-fatality landslide events are differentiated from single-fatality landslides, which increased with time independent of trigger (Fig. 6c). By country, most construction-triggered landslide events occurred in India (28 %), followed by China (9 %), Pakistan (6 %), the Philippines (5 %), Nepal (5 %) and Malaysia (5 %; Fig. 9a). On average construction-triggered landslide events have killed 3 people per event, but a particularly severe landslide in Shenzhen, China, in December 2015 killed 77 people. The event involved the collapse of construction waste on worker quarters in an industrial site. Interestingly, the context in which the landslides occur differs between countries. In China, the majority of events (52 %) occur in urban construction sites, while very few landslides occur on roads (7 %). Conversely, in India and Nepal, 30 and 43 % of landslide events triggered by construction occurred on roads.

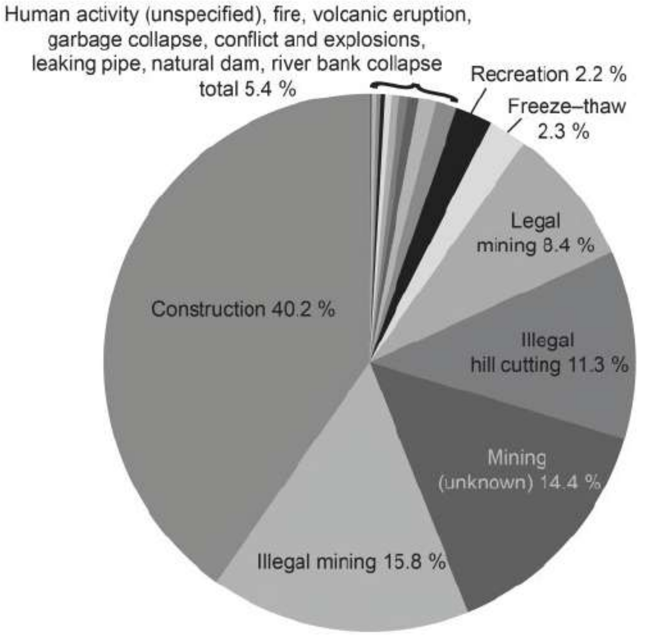

Figure 7 Distribution of triggers of NSNR landslide events (770 events).

Transportation is a "crucial driver of development" (World Bank, 2018b); however, in mountain regions roads are closely connected with landslide risk (Lennartz, 2013). The road network in Nepal has quadrupled in length over the last 18 years (Govt. of Nepal, 2016), and in India it has nearly tripled in length in 24 years (Govt. of India, 2016). Population growth is frequently accompanied by the expansion of infrastructure and settlements (Gardner and Dekens, 2007), and this is true in India and Nepal, which have grown by ~7 % between 2010 and 2015 (World Bank, 2018a). Both countries are on a trajectory to expand their national road networks further. Increased landslide activity in the Himalayan region has been associated with road construction (Ives and Messerli, 1989; Haigh et al., 1989; Valdiya, 1998; Barnard et al., 2001; Petley et al., 2007; Sati et al., 2011; Singh et al., 2014). Hearn and Shakya (2017) highlighted that road construction without proper route choice, engineering design and management of spoil increases landslide susceptibility. Fatal landslides triggered by road construction indicate that excavation may not always be undertaken with due care and appropriate slope engineering. Furthermore, the coincidence of construction worker and road user fatalities from the same landslide suggests that there is pressure to keep roads under construction open. Ives and Messerli (1989) emphasised the economic impact when roads are closed.

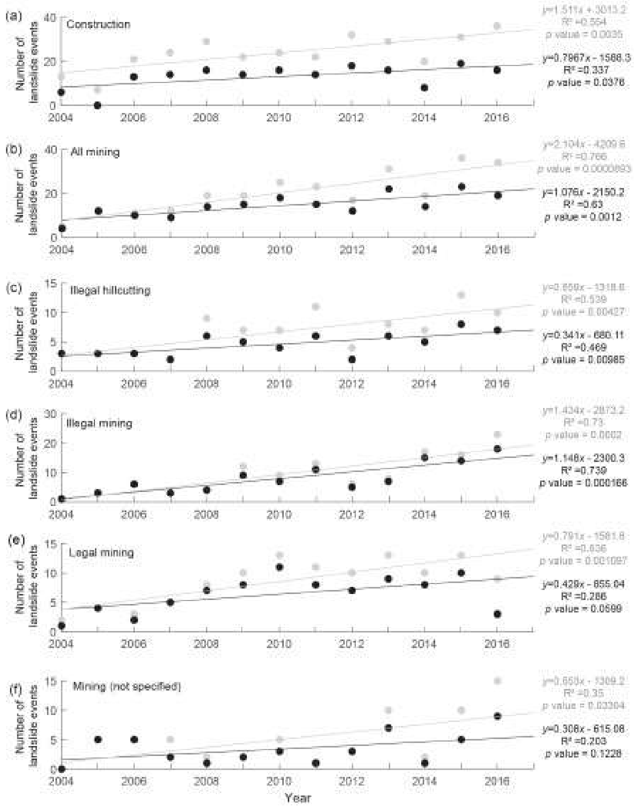

Figure 8 Number of landslide events triggered per year by **(a)** construction, **(b)** mining, **(c)** illegal hill cutting, **(d)** illegal mining, **(e)** legal mining and **(f)** mining (not specified). The black series contains only multi-fatality landslide events. The grey series contains single and multi-fatality landslide events.

Between 2004 and 2016, China experienced a 6 % growth in population to 1.379 billion and a 16 % rise in the proportion of the population living in urban areas (World Bank, 2018a). Urban growth in China is driven by political policy for economic growth; economic reforms from 1978 opened China's markets to foreign investors and relaxed migration controls, prompting rapid rural–urban migration (Ma, 2002; Anderson and Ge, 2004). Although urbanisation is encouraged by China to increase domestic consumption, urban growth is often uncontrolled (Fang and Pal, 2016), leading to rapid land conversion, dispersion and fragmentation of development (Schneider and Woodcock, 2008). Critically, many of China's largest cities are bounded by mountains, and urban sprawl is encroaching on land unsuitable for development (Yu et al., 2011). Reports in the database indicate that fatal landslides in urban construction sites in China often occurred when engineered cut slopes failed above the construction site (e.g. Zhang et al., 2012), from improper construction of foundations leading to building collapse before completion (e.g. Srivastava et al., 2012) or from mismanagement of construction and demolition waste (e.g. Yang et al., 2017). In these entirely preventable circumstances, explicit national regulation and enforcement should reduce construction-related landslide impact in China.

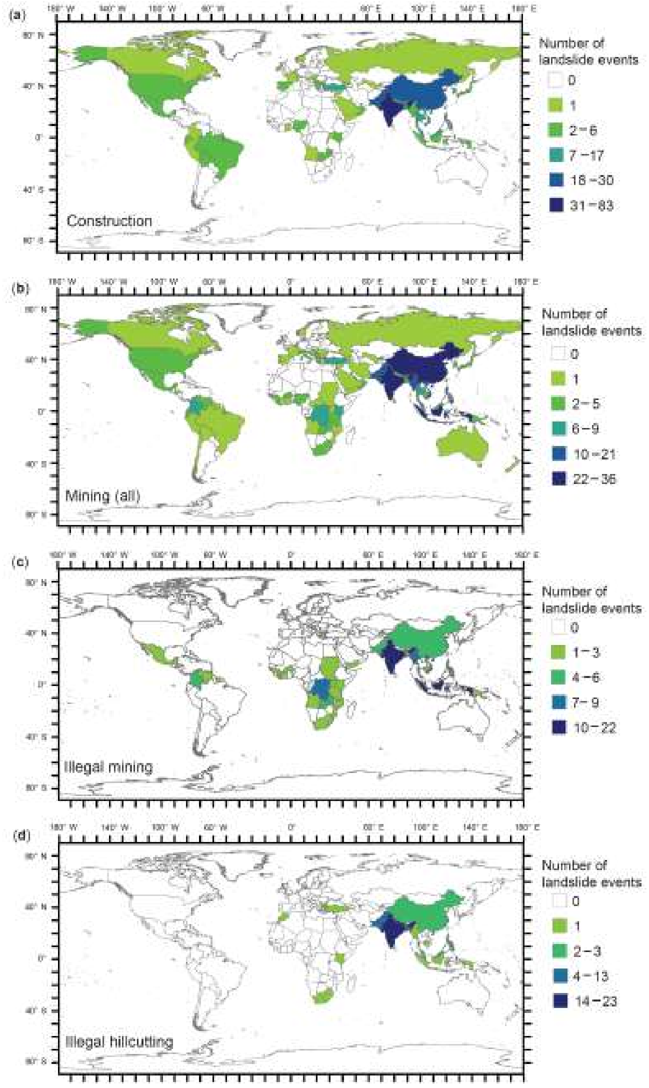

Figure 9 By country, the number of landslide events triggered by **(a)** construction, **(b)** mining, **(c)** illegal mining and **(d)** illegal hill cutting, between 2004 and 2016.

The increase in events triggered by mining is driven by the increase in landslides triggered by illegal or unregulated extraction (Fig. 8d); landslides triggered by legal mining (Fig. 8e) or where the legitimacy of the mining is unknown (Fig. 8f) do not show a statistically significant trend. By country, India (12 %), Indonesia (11.7 %), China (10 %), Pakistan (7 %) and Philippines (7 %) contribute most to the record of landslides triggered by mining (Fig. 9b). Fatal landslides triggered by illegal mining practises have occurred in 32 countries (Fig. 9c). By number of events, Indonesia (24) and India (15) rank the highest, but by number of fatalities Myanmar (403 fatalities from 9 landslide events) stands out. Shifts in spending power and the infusion of the internet and smart technology in daily life have driven an exponential increase in the consumption of electronics, placing pressure on the demand for rare earth elements (Dutta et al., 2016). Furthermore, growth in the precious stone market fuelled by both economic uncertainty and a growing middle class in Asian nations such as China, where gemstones are a key part of cultural heritage (The Economist, 2011), is thought to have led to an increase in the number of small-scale mining operations globally (Hruschka and Echavarría, 2011) and the upscaling of small-scale mines to larger-scale operations. Fatal landslides in Myanmar (Burma) have significantly increased because of the unregulated expansion in jade mining within the Kachin state. Critically, the high value of jade and lack of enforced operator accountability appear to be driving poor mining practises, which place workers and local residents at risk of slope collapse (Global Witness, 2015). Demand for rare earth elements and gemstones is thus driving an increase in mining-related landslides, with the potential for landslide occurrence to rival that associated with rural road expansion.

Cutting slopes for the purposes of obtaining earth surface materials, or to alter slope geometry during construction, may result in slope failure if the site is not properly engineered. The term hill cutting is used here in relation to discrete slopes that have been altered without permission for the purposes of small-scale construction, earth material extraction or agriculture. Hill cutting is most strongly associated with urban areas in Bangladesh in the academic literature (e.g. Chittagong; Ahmed, 2015 or Sylhet; Islam et al., 2006). In the fatal landslide database it is an increasing problem in Bangladesh, India and Nepal (Figs. 8c and 9d). Most fatalities occurred as people collected hillslope materials for construction of their housing in rural communities, and reports indicate those involved were from poor families living in informal settlements. In total, 11 of the 87 landslide events were directly related to the practice of using hillslope coloured clay for the decorative coating of houses for a religious festival; of these, 9 occurred in Nepal. Critically, children are often caught up in slides triggered by hill cutting in Nepal: at least 40 % of landslide victims were children, while a further 25 % of victims were a combination of adults (predominantly women) and children working together. Conversely, in Bangladesh the majority of victims were adults (78 %) of which 79 % were male. In Nepal, India and Bangladesh, clay is an important local building material for housing, particularly in settlements not connected to the road network. There is a legal framework in Bangladesh to prevent hill cutting (Building Construction Act 1952 and 1990, and the Bangladesh Environmental Conservation Act 1995; Murshed, 2013). Building codes in Nepal provide basic guidance on slope stability, specifically slope excavation, identification of slope instability and construction of foundations (DUDBC, 1994); however, residents in rural communities may not have access to this information and be unaware of the hazard (Oven et al., 2008). Furthermore, in India it was noted that building regulations do not account for the geo-environmental context of the settlement, sometimes lack clarity and are difficult to uphold due to a shortage of technical experts and inadequate provision to stop illegal activity (Kumar and Pushplata, 2015).

While this section discusses fatal landslides triggered by human activity, many rainfall-triggered landslides occur on slopes which have been modified during construction (82 landslide events), agriculture and forestry (45 landslide events) and mining (123 landslide events) or at sites where storage of waste has not been poorly managed (16 landslide events). Of course, it is expected that the majority of fatal landslides (94 %) will occur within settlement boundaries or along infrastructure, but it is evident from this database of events that human action damages slopes, increasing their susceptibility to fail.

4 Discussion and conclusion

With the benefit of a 13-year time series, this study builds on past analyses of the GFLD, not only providing an update on the spatial and temporal distributions of landslide impact but also serving to highlight the importance of annual climate variability in specific landslide-prone regions on the global record. In addition, it provides new insights into the impact of human activity on landslide incidence. The data do not indicate a discernible long-term increase or decrease in global landslide impact; rather, the record shows that there is considerable interannual variability in global landslide event incidence. The more active years have been associated with recognised regional patterns of rainfall, in part driven by global climate anomalies, but there is no simple relationship with, for example, ENSO. Relating climate modes to patterns of landsliding is challenging because of climate complexity and change, requiring datasets of 30 years or more. Increased understanding of the impact of ENSO diversity on regional climate will improve models forecasting seasonal rainfall distribution and landslide impact. This is particularly important in acutely affected areas such as India, China and Nepal.

Human disturbance (land use change) may be more detrimental to future landslide incidence than climate change (Crozier, 2010; Anderson and Holcombe, 2013), and this is evidenced by a number of studies (Innes, 1983; Glade, 2003; Soldati et al., 2004; Imaizumi et al., 2008; Borgatti and Soldati, 2010; Lonigro et al., 2015). A comprehensive review of climate–landslide studies by Gariano and Guzzetti (2016) found the majority of papers (80 %) showed a causal relationship between climate change and landslides. However, the authors highlight the significant uncertainties surrounding our current understanding of climate–landslide interacttion. Specifically, the limited geographic scope of research, challenges in downscaling climate scenarios to slope stability models and complex interactions between natural and human induced drivers of landslide activity. Gariano and Guzzetti (2016) demonstrate that different climate variables will effect different landslide types and slope settings. There is a high confidence that glacial retreat and permafrost degradation will increase slope instabilities in high mountain areas in the long term, and high confidence that changes in heavy precipitation will affect some regions. However, there is low confidence in projections for shallow landslide activity in temperate and tropical regions because of the coincident effects of human land use practise (Seneviratne et al., 2012). Further research is required to evaluate the impact of climate change and human disturbance in different localities.

Our analyses have demonstrated that fatal landslide occurrence triggered by human activity is increasing, driven by construction, illegal mining and illegal hill cutting. Fatal landslides occur when construction and mining (1) do not apply appropriate slope engineering, (2) mismanage spoil and (3) do not undertake a feasibility assessment (Hearn and Shakya, 2017). Appropriate building regulations that account for the geo-environmental context of the settlement, provide clear guidance on engineering and are enforced by local technical experts are paramount in managing landslide risk associated with urbanisation and natural resource exploitation.

Holcombe et al. (2016) emphasised that planning policy alone is not sufficient to control landslide risk in developing nations. This is due to the rapid and informal nature of construction and low income of residents, who cannot finance expert guidance when building their homes. Settlements are often built on hazardous land around urban centres and on roadsides because of the benefits of service access and employment opportunities (Smyth and Royle, 2000; Oven et al., 2008; Lennartz, 2013; Anhorn et al., 2015). Hill cutting is the dominant driver of instability during informal construction (Holcombe et al., 2016), and our results indicate that fatal landslide events triggered by hill cutting are increasing in Bangladesh, India and Nepal. Several landslides were triggered when people cut slopes to collect coloured clay to decorate their houses for religious festivals. Here, communication of landslide risk by local non-governmental organisations (NGOs) could prevent future fatalities from this practice. Where governments are limited in capacity at a local level, NGOs are important in implementing disaster risk reduction (Jones et al., 2016), such as supporting community-based slope engineering (e.g. Mossaic; Anderson and Holcombe, 2006).

Reporting of fatal landslides is likely to increase with the global growth in mobile technology and internet access, particularly in remote mountain regions. Furthermore, advances in web mining (data retrieval from the internet based on search criteria) and text mining (transforms unstructured data into structured to discover knowledge) using machine learning offer methods to improve capture of landslide reporting and data evaluation (e.g. Bhatia and Khalid, 2008; Kumar and Jaiswal, 2017). Global landslide databases are designed to capture general trends in landslide occurrence rather than provide data for local quantitative risk assessment. Continued collection of the database will develop our understanding of the effect of climate and human disturbance on global landslide impact. The dataset is a useful tool in identifying acutely landslide-prone parts of the world and specific local drivers of landslide impact, thereby highlighting locations which would benefit from further development in early warning technology, landslide risk assessment and community capacity building. This is in support of the future directions of the International Consortium on Landslides (Alcántara-Ayala et al., 2017).

Data availability

The GFLD (2004 to 2016) data are available to view at ESRI ArcGIS online at https://shefuni.maps.arcgis.com/apps/webappviewer/index.html?id=98462998953c4f1fbd7caaa166373f63 (Froude and Petley, 2018). A full release of the database is scheduled for later in 2018. The release will be publicized on Dave's landslide blog: https://blogs.agu.org/landslideblog/ (last access: 18 July 2018).

Appendix A

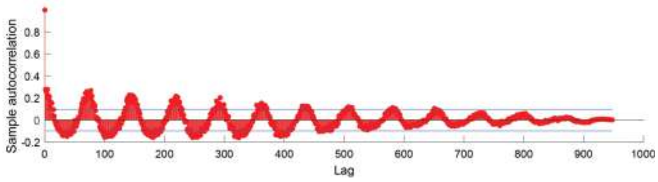

Figure A1 Sample autocorrelation plot for the pentad rainfall-triggered landslides. The 99 % confidence interval is shown by the blue horizontal lines.

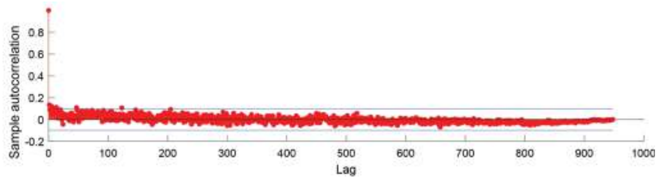

Figure A2 Sample autocorrelation plot for the pentad NSNR landslides. The 99 % confidence interval is shown by the blue horizontal lines.

Appendix B

Table B1 Hierarchical linear regression results comparing the impact of seasonality in geographical regions with the global mean number of landslides per pentad through the annual cycle (see Fig. 4). The data series for each geographical region are sequentially added into the regression (such that the second row of the table is a regression of South Asia + SE Asia with the global series).

Predictor variables	N (cumulative)	% (of total N)	R^2	ΔR^2
+ South Asia	1295	31.50	0.4962	
+ SE Asia	2121	52.27	0.7365	0.2403
+ East Asia	2804	71.88	0.8618	0.1253
+ South America	3145	82.25	0.9129	0.0511
+ Central America	3340	88.03	0.9575	0.0446

Supplement

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Author contributions

DP developed the methodology (2002–2003) and has consistently collected the database since 2004. MF analysed the data and wrote up the results for this submission. DP contributed to writing.

Competing interests

The authors declare that they have no conflict of interest.

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Corrigendum: In the original image the labels "mining (not specified)" and "legal mining" were switched for panels (e) and (f). This has been corrected and the new image is printed below.

How to cite.

Froude, M. J. and Petley, D. N.: Global fatal landslide occurrence from 2004 to 2016, Nat. Hazards Earth Syst. Sci., 18, 2161–2181, https://doi.org/10.5194/nhess-18-2161-2018, 2018.

CHILDA – Czech Historical Landslide Database

Michal Bíl, Pavel Raška, Lukáš Dolák, and Jan Kubeček

Abstract

National and regional historical landslide databases are increasingly viewed as providing empirical evidence for the geomorphic effects of ongoing environmental change and for supporting adaptive territorial planning. In this work, we present the design and current content of the Czech Historical Landslide Database (CHILDA), the first of its kind for the territory of Czechia (the Czech Republic). We outline the CHILDA system, its functionality, and technical solution. The database was established by merging and extending the fragmented regional datasets for highly landslide-prone areas in Czechia. Currently, the database includes 699 records (619 landslides, 75 rockfalls, and 5 other movement types) encompassing the period from the oldest determined records (1132) up to 1989, which represents an important cultural, political, and socioeconomic divide.

How to cite.

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1 Introduction

Historical landslide inventories and databases are among the key challenges within landslide risk reduction efforts as they fill the gap between, on the one hand, the landslide occurrence in the past environments studied with the use of various documentary proxies and, on the other, the present-day landslides, for which different monitoring and mapping techniques may be used (e.g. Glade et al., 2001; Raška et al., 2015; Piacentini et al., 2018). In light of the recent global climate change, the historical landslide databases contribute a better understanding to changes in various meteorological triggers of landslides in different environmental settings (Gariano and Guzzetti, 2016; Caracciolo et al., 2017). Given the severe impacts of landslides on society (Froude and Petley, 2018), these databases also make it possible to identify changes in hotspots of landslide occurrence and the character of their impacts (Salvati et al., 2015; Klose et al., 2016). In both these respects, the historical databases complement current landslide inventories that can be used to trace the spatial patterns in landslide occurrence and their causative factors (Van Den Eeckhaut and Hervás, 2012; Herrera et al., 2018; Marc et al., 2018). Within the landslide hazard and risk assessments, the historical landslide databases provide evidence as it is generally assumed that past landslide occurrence frequencies may be used to describe the probabilities of landslide occurrence in the near future (Remondo et al., 2008; Van Den Eeckhaut et al., 2009; Wu and Yeh, 2020).

Connecting these directions, increasing attention has been also paid to revealing the vulnerabilities and adaptive behaviours of past societies regarding landslides (Tropeano and Turconi, 2004; Caloiero et al., 2014; Klose et al., 2016; Raška, 2019; Rossi et al., 2019; Klimeš et al., 2020). These studies argue that historical landslide databases – if approached critically – may inform current efforts for adaptive management of landslide risks (Klose et al., 2016; Raška and Dubišar, 2017). Historical landslide databases have been recently established for various countries and regions, for instance, in Italy (Guzzetti et al., 1994; Piacentini et al., 2018), Nicaragua (Devoli et al., 2007), USA (Elliott and Kirschbaum, 2007), Norway (Hermanns et al., 2013), the UK (Taylor et al., 2015), Germany (Damm and Klose, 2015), and Portugal (Pereira et al., 2014), most of them covering ca. the last 150 years but some databases also including scarce records dating back as early as the twelfth century.

The aim of this work is to present the Czech Historical Landslide Database (CHILDA), a project that unified and signifcantly extended the fragmented existing regional databases and established an open-access and concurrently updated map inventory of historical landslides in Czechia. The presented database thus further fills in the gap of missing historical databases for central European mid-mountain environments (Damm and Klose, 2015). Within this paper, *landsliding* is used as a generic term covering all major types of rapid mass movements (cf. Hungr et al., 2014) that are usually recorded in the documentary data. Slow slope deformations are not studied here since they usually did not cause rapid harm to society and have not been registered by past societies. For CHILDA (2021) content, we only differentiate between the three following groups according to major mechanisms: (a) landslides sensu stricto (also including spreading and flows) and (b) rockfalls (including topples) in solid bedrock, while (c) all remaining mass movements are grouped as "other". This rough classification is used since the documentary data often do not allow for detailed and reliable identification of the mass movement type.

In the following sections, we will first review the previous studies on historical landslides in Czechia with emphasis given to attempts to establish systematic historical landslide databases. We will then outline the availability of the documentary sources and present a design of CHILDA. Finally, the current content of this database and its completeness will be presented in a comparative perspective along with discussion of its future directions. Although CHILDA is an open database, the last analysed year was set to 1989 for the purpose of this study. The year is considered an important cultural, political, and socioeconomic divide in the recent history of Czechia, turning the country into a democratic regime. For the landslide research this shift implies important change in public data availability as well as in approaches to scientific inquiry regarding landslides. While CHILDA remains open for newer records after 1989, its main objective is to collect and present the data on historical landsliding before this date and known only from documentary data.

2 Landslides in Czechia

2.1 Landslide predispositions in Czechia

Despite the fact that Czechia can be generally considered a low-risk country, given the relatively low landslide frequencies and impacts (Klimeš et al., 2017), the country displays high spatial variability in landslide occurrence with some highly landslide-prone regions due to their predisposition and presence of causative factors. Among the areas the most affected by landslides are the Outer Western Carpathians (OWC), NW Czechia (České středohoří Mts, Děčínská vrchovina), and several of the scattered spatially limited areas across the country (see Fig. 1).

The eastern part of Czechia, OWC, is particularly susceptible to landsliding. As a consequence, for example, of the 1997 landslide period as many as 3700 individual landslides were mapped in that region (Krejčí et al., 2002). High numbers of reactivated landslides were also further identified during the periods of intense landsliding which followed, specifically in 2006 (Bíl and Müller, 2008), and 2010 (Pánek et al., 2011). The Registry of Slope Deformations of the Czech Geological Survey (2012a, http://www.geology.cz, last access: 18 August 2021) contains in all approximately 14 500 landslides in this area of the Czech part of the OWC (7200 km^2), which was 82 % of all the landslides registered within Czechia (Bíl et al., 2016).

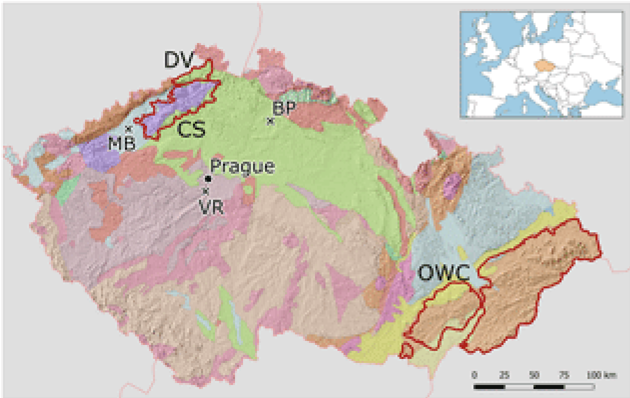

Figure 1 Delimitation of the primary areas where landsliding concentrates in Czechia. Neogene volcanic rocks (CS – České středohoří Mts), Mesozoic sandstones (DV – Děčínská vrchovina), Neogene and Quaternary sediments (MB – Most Basin) on the west, Mesozoic sandstones in central parts of Czechia (BP – Bohemian Paradise sandstones), and Mesozoic and Tertiary flysch belt (OWC – Outer Western Carpathians) in the east of Czechia represent the most susceptible parts to landsliding. VR – concentration of rockfalls along the Vltava River; https://mapy.geology.cz/arcgis/rest/services/Inspire/GM2_5mil/MapServer (last access: 19 August 2021; Czech Geological Survey Map Server, 2012b). © Czech Geological Survey.

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2.2 Historical landslide research in Czechia

2.2.1 The beginning of landslide research in Czechia

The first works on landsliding in Czechia are dated to the eighteenth century (e.g. Strnad, 1790), followed by works emerging as of the end of the nineteenth century (Zahálka, 1890; Dědina, 1896; Woldřich, 1899) and at the beginning of the twentieth century (Čermák, 1912; Dědina, 1916). More systematic landslide research started, however, in the 1920s with the work of Záruba (1922, 1923, 1926, 1938). Particular attention was paid to landslide areas in the Pavlovské vrchy situated in OWC (Jüttner 1931, 1937; Stejskal, 1931; Woldřich and Stejskal, 1934). Záruba and Myslivec (1942) documented landslides related to transportation infrastructure in OWC. Landsliding in the broader area of the city of Zlín (OWC) was described by Krejčí (1943). The first Czech modern landslide classification was published by Záruba and Mencl (1954).

2.2.2 Systematic works describing landslide occurrence based on historical data

We present here an overview of works from Czechia which created at least a regional landslide chronology based on documentary data analyses. The only systematic studies of landslide occurrence, based on a range of historical sources in Czechia, were conducted by Špůrek (1967, 1972, 1985). These studies were mainly based on the investigation of articles published in national newspapers covering the territory of former Czechoslovakia (and also mentioning landsliding all over the world). The recorded information includes each landslide date, location, type, and amount of damage as well as the bibliographic source.

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3 Design of the CHILDA database

3.1 Data availability

Czechia has at its disposition an extremely diverse and extensive range of documentary data that may be explored to build historical landslide inventories. The number of these sources have been, however, subjected to academic scrutiny mostly in historical climatology and hydrology (Kjeldsen et al., 2014; Brázdil et al., 2018a). Similarly, Bíl et al. (2020) combined different documentary and archaeological data to compile a chronology of landsliding in the Pavlovské vrchy (Czechia, OWC) and described the basic historical landslide terminology. The conceptual differences in hydrometeorological and geomorphologic hazards do not allow for uncritical transposition of the climatological insights into the historical landslide research and therefore call for new insights into the potential of the documentary data (Crozier and Glade, 1999; Raška et al., 2014b).

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3.2 Database structure

The database structure reflects the specific nature of documentary data, which usually do not allow to distinguish details of movement types, magnitudes, or velocities. For the individual attributes, we considered the existing classifications of movement types (Hungr et al., 2014), temporal dimensions of landsliding (Flageollet 1996), and landslide impacts (Alimohammadlou et al., 2013), and where possible, the attributes were designed to allow comparability with these classification schemes. Attributes related to each database record are presented in Table 1. Some of the attributes are added by users via a form. The items with an asterisk are mandatory and the items which are not part of the input form are underlined. They are processed automatically, within the system.

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3.3 Web-map application

The database can be accessed through a web-map application at https://childa.cz/ (last access: 19 August 2021) (Fig. 3). CHILDA is administrated and hosted on the CDV – Transport Research Centre servers. The software requirement is as follows: PostgreSql/PostGIS, php, php NetteFramework, HTML, CSS, JQuery.

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4 Results

4.1 Landslide records in CHILDA

We present below an overview of data contained in CHILDA for the 1132–1989 period. The database contains 699 records, 619 of them categorised as landslides, 75 as rockfalls, and 5 as "other" kind of mass movements (earth flow, rockslide, or human-induced landslide). As regards temporal accuracy (see Table 1 for explanation), 231 records were determined exactly at single-day precision, 17 records are known with a weekly and 88 with a monthly precision. In total, 363 records were only attributed to a given year. Concerning the location accuracy, 111 records were localised precisely, 71 records with a precision of "tens of metres", 260 records to "hundreds of metres", and 478 to kilometres (mostly between 1–2 km, exceptionally up to 5 km in the mountain terrains of Czechia).

Table 1 Structure of records in CHILDA.

Field name*	Description	Field type
ID	Unique identifier of a landslide	Number
Type*	Determination of kind of landsliding	List: landslide; rockfall; earthflow; debris flow; human-induced landslide
Position*	Latitude and longitude of the record inserted via a click on the map	WGS 84 coordinates
Locality*	Description of the locality	String
Accuracy*	Describes the spatial precision of landslide localisation by DB (database) user (not a precision in an original source)	List: metres; tens of metres; hundreds of metres; kilometres
MASL	Height above mean sea level – landslide highest point elevation	Metres
Count	The number of landslides related to the particular location, given its accuracy; default value 1	String
Start*	The earliest possible date for the beginning of landsliding indicated by a record	Date
End*	The latest possible date for the beginning of landsliding as indicated by a record	Date
Period	Shows an interval during which the landslide originated. It is computed as End–Start.	String; an exact day or and interval, e.g. September 1941–May 1942
Causes	Description of landslide cause; more causes can be selected	List: earthquake; lithology; flooding; precipitation; mining; snow thaw; storm; artificial cause
Extent	Extent of landsliding	List: small: less than $100\,m^2$, volume up to $100\,m^3$; medium: up to 1 ha, volume up to $1000\,m^3$; large: more than 1 ha, volumes larger than $1000\,m^3$
Impact	List of elements at risk and losses caused by landsliding; more impacts can be selected	List: human fatality; human injury; buildings; transport infrastructure; other infrastructure (mine, water tower, utilities, etc.); landscape including old mines, etc.
Remedies	Kind of remediation if applied	String
Source*	Full citation of the source of the landslide record	String
Details	Additional information and original data availability and accessibility (e.g. museum, archive, private collection)	String
Notes	Other relevant information about landsliding	String
Photo	More than one graphics file can be attributed to a record, e.g. photo, map, a copy of a written source	Graphics file, pdf

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4.2 The oldest records on landsliding

The issue of the precise determination of dates of landslide activity becomes more important when we look back in history. The oldest records describing landslides in Czechia suffer from spatiotemporal inhomogeneity. CHILDA currently contains 14 reports of mass movements which took place before 1770, the first most important landslide year (see Table 4). It is important to mention that in 50 % of all recorded cases, citations referring to historical landslides in this study came from the Špůrek landslide catalogue (1972). Because of our efforts at maximum authenticity, we took over these citations although we were not able to study some referenced citations personally in certain cases.

Table 4 The most important 15 landslide years (1770-1989) when at least 10 records were found.

Year	1770	1898	1899	1900	1915	1919	1926	1937
n	*17*	*39*	*13*	*61*	*10*	*10*	*32*	*10*
Year	1938	1939	1940	1941	1965	1967	1970	
n	*11*	*46*	*19*	*51*	*38*	*14*	*14*	

The oldest known written report describes a rockfall in Prague–Chuchle (VR area) on 19 January 1132 (Strnad, 1790). More detailed information about three landslide events in spring 1531 is described by chroniclers from Lito-měřice and Bílina (CS area). Landsliding was reported from the beginning of April until the middle of May and affected Radobýl Hill near Litoměřice and Holý vrch near Zahořany village. Vineyards planted on the hills and slopes slid and two great parts of Radobýl Hill slipped down, including trees and plants. Similarly, a large portion of Holý vrch slid at that time and a series of other landslides were observed (Smetana, 1978). In the wet spring of 1531, several landslides also occurred in the surroundings of the nearby Bílina River after a flood (Hutter, 1891).

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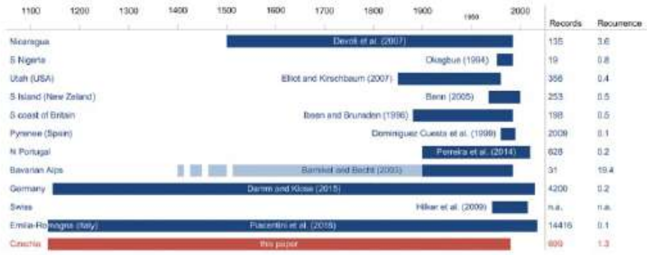
5 Discussion

5.1 CHILDA and other historical landslide databases

We presented an overview of the CHILDA database where as many as possible records on historical landsliding, which took part in the area of modern Czechia, were collected. This database currently contains 699 records (between 1132 and 1989) and can be compared to other similar databases which have been completed in other countries (Fig. 9).



Fugure 9 Compasison of CHILDA and other existing historical landslide databases in terms of the number of records and recurrence.
Note: dark-blue stripes mark the periods under study. In the case of compound (multi-hazard) databases, light-blue stands for landsliding. Dashed strips represent an unspecified beginning (e.g. since the fifteenth century without explicit dating of the oldest record)

It should be noted, however, that similarly to other databases CHILDA displays high asymmetry in the number of recorded events over time. First, the sole oldest record dated to 1132 extends the span by 4 centuries as further records are only dated to 1531. Second, the majority of records (93 %) relates landsliding that occurred since 1850. In contrast, and unlike the other databases, CHILDA also records only a few increased landslide frequencies in the pre-industrial periods, namely the 1770 landslide year (17 landslides) resulting from the central European adverse climate (Raška et al., 2016) and 1817 (with five landslides) possibly influenced by the Tambora eruption in 1815 (Brázdil et al., 2016b).

5.2 Limitations of the CHILDA database

As with similar databases which focus on historical records and therefore depend on availability, accessibility, and reliability of original sources, CHILDA also has certain limitations that may be grouped in the following kinds of uncertainties.

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6 Conclusions

We presented the online landslide database CHILDA (Czech Historical Landslide Database), which summarises information about landslides which took place in the area of Czechia (the Czech Republic). The database is freely accessible via the http://childa.cz/ (last access: 19 August 2021) website and currently includes 699 records (spanning the 1132–1989 period). The oldest record relates to a rockfall which took place in 1132. In total, the database doubled the number of records known from the previous historical database in Czechia. We further described in detail another eight of the oldest records (1531 to 1730) and analysed centennial and decadal frequencies of landslide records. It was demonstrated that 55 % of all recorded landslide events occurred only within 15 years of the extreme landslide incidence. Finally, the limitations of the documentary data sources have been summarised pointing at uncertainties within the database. The future research direction should focus on analysing historical landslide triggers and their thresholds, on changes in spatiotemporal patterns of landslide impacts on society, and on narratives of societal adaptive management to landslide risk.

(https://nhess.copernicus.org/articles/21/2581/2021/)

Σημείωση Εκδότη

Στο άρθρο αναφέρεται ότι Βάσεις Πληροφοριών Ιστορικών Κατολισθήσεων έχουν αναπτυχθή στην Ιταλία, Νικαράγουα, Νορβηγία, Ηνωμένο Βασίλειο, Γερμανία, Πορτογαλία, Ελβετία και σε συγκεκριμένες περιοχές της Ισπανίας, Νέας Ζηλανδίας και Νιγηρίας.

Πρόσφατα, δημοσιεύθηκε εργασία με τίτλο «Historical landslides that have resulted in fatalities in Canada».

Βλέπουμε ότι εδώ και αρκετά χρόνια γίνεται διεθνώς προσπάθεια για την δημιουργία Βάσεων Δεδομένων και την σύνταξη χαρτών με περιοχές με κατολισθητικά φαινόμενα, εργαλεία πάρα πολύ χρήσιμα για την ανάπτυξη κάθε χώρας και τα σχετικά έργα υποδομών.

Θεωρώ ότι πρέπει να γίνη σύντομα κάτι αντίστοιχο και στην Ελλάδα. Κατά καιρούς έχουν παρουσιασθή εργασίες και χάρτες, σχετικά με το αντικείμενο, κατά κανόνα αποσπασματικά. Τρεχόντως, η Ελληνική Αρχή Γεωλογικών και Μεταλλευτικών Ερευνών (πρώην ΙΓΜΕ) εκπονεί ερευνητικό πρόγραμμα (θα τελειώση το 2023) για την συνολική καταγραφή των κατολισθήσεων στον ελληνικό χώρο και την σύνταξη σχετικού χάρτη επικινδυνότητας. Περιμένουμε τα αποτελέσματα με ενδιαφέρον. Θα ήταν καλό, όμως, η ΕΑΓΜΕ να συνεργασθή στο έργο με την ΕΕΕΕΓΜ και την Επιστημονική Επιτροπή Εδαφομηχανικής του ΤΕΕ και, ενδεχομένως, με άλλους επιστημονικούς φορείς που ασχολούνται με το αντικείμενο (π.χ. Τομέα Δυναμικής Τεκτονικής Εφαρμοσμένης Γεωλογίας του τμήματος Γεωλογίας και Γεωπεριβάλλοντος του Εθνικού και Καποδιστριακού Πανεπιστημίου Αθηνών).

Vulnerability and Site Effects in Earthquake Disasters in Armenia (Colombia). I - Site Effects

Francisco J. Chávez-García, Hugo Monsalve Jaramillo, Marisol Gómez Cano and JoséJ. Vila Ortega

Abstract: The city of Armenia, Colombia has been repeatedly subjected to moderate magnitude earthquakes. Damage in that city for the 1999 (Mw6.2) event was disproportionate (maximum observedEMS-92 intensity of IX), even considering the small epicentral distance (18 km). Two main factors have been invoked: Site effects and vulnerability of the building stock. We re-analyze available data onsite effects, including: Records of aftershocks of the 1999 event, ambient noise records obtained using standalone stations, array records of ambient noise, and available shear wave profiles from seismiccone measurements. We estimate local amplification from spectral ratios of earthquake records relative to a reference site, the horizontal relative to the vertical component (HVSR, Horizontal-to-Vertical Spectral Ratios) of earthquakes and ambient noise records, and ratios of response spectra relative to a reference site or to simulated ground motion. These estimates are compared to amplification functions computed for 1D soil models, inverted from microtremor array observations. Our estimates of site effects for Armenia are therefore robust and bring together results previously available only in internal reports. We show that spectral ratios relative to a reference site may fail to estimate the amplification level. Site effects in Armenia are relatively homogeneous. Although site amplification is very significant and contributed to the observed damage, it does not account for the irregular damage distribution observed in 1999.

https://www.researchgate.net/publication/326282835_Vulnerability_and_Site_Effects_in_Earthquake_Disasters_in_Armenia_Colombia_I-Site_Effects

Vulnerability and site effects in earthquake disasters in Armenia (Colombia) – Part 2: Observed damage and vulnerability

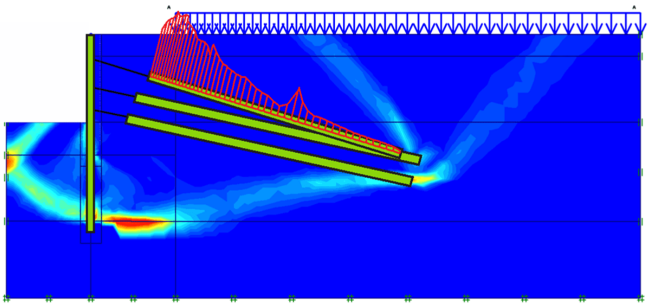
Francisco J. Chávez-García, Hugo Monsalve-Jaramillo, and Joaquín Vila-Ortega

Abstract

Damage in Armenia, Colombia, for the 25 January 1999 (M_w=6.2, peak ground acceleration (PGA) 580 Gal) event was disproportionate. We analyze the damage report as a function of number of stories and construction age of buildings. We recovered two vulnerability evaluations made in Armenia in 1993 and in 2004. We compare the results of the 1993 evaluation with damage observed in 1999 and show that the vulnerability evaluation made in 1993 could have predicted the relative frequency of damage observed in 1999. Our results show that vulnerability of the building stock was the major factor behind damage observed in 1999. Moreover, it showed no significant reduction between 1999 and 2004.

https://nhess.copernicus.org/articles/21/2345/2021/

The Value of Numerical Modeling for Geo-Structural Engineering



Numerical modeling uses complex computer programs to build a digital model of a site from which to calculate how a design will perform for various loading conditions. These methods avoid some of the simplifying and conservative assumptions that get made in simpler approaches. They help improve the efficiency of a design, predict how a design is likely to perform, show how a structure's foundation and the groundwater will interact as a unit, and provide insight into the important mechanisms controlling how the design will perform. Improved predictions, better understanding of complex behavior, and optimized designs with minimal assumptions help reduce risks and costs for many projects.

What is Numerical Modeling? Numerical modeling uses digital computer models to analyze stress, strain, and deformations in a project with complicated soil, water and structural geometries and materials. Numerical modeling methods include the finite element method (FEM), the finite difference method (FDM), the boundary element method (BEM), and the discrete element method (DEM). Nonlinear material properties can be considered which allow designs to be optimized with some degree of non-linear behavior and yielding which results in less conservatism and less cost. Numerical modeling can be used to analyze almost any type of geostructural problem in two or three dimensions.

When is Numerical Modeling Needed? Numerical modeling is used when the structure/soil/water geometry and materials are too complicated to solve with closed-form analytical equations. The methods rely on breaking the complex geometry into smaller pieces. The behavior of each small piece is described with a stress-strain model that represents the basic understanding of each material's behavior (bending of a beam, stress/strain behavior of a soil cube, flow of water through soil, etc.). The numerical model combines engineering mechanics equations for force equilibrium, conservation of mass, kinematic continuity, and stress-strain-strength behavior of each piece into a large set of equations describing how the pieces interact. Matrix algebra is used to combine the pieces and equations to create the digital model that gives stresses, strains, and displacements throughout the geometry for each specific load case. Examples of different types of problems addressed with a numerical model are described herein.

Evaluating Potential to Create a Seepage Barrier with Ground Freezing

The first example shown in Figure 1 is for a client that was designing a groundwater cutoff in an area with flowing groundwater. Flowing groundwater makes it difficult to freeze the ground (a construction technique used to provide temporary earth support and groundwater control). The left figure in Figure 1 shows a plan view (looking down from the top) of frozen soil in blue around the freeze pipe shown in white. The right three figures in Figure 1 show the frozen soil (in blue) for conditions of increasing velocities of groundwater flow. The flow direction is from the bottom to the top in the figure. Numerical modeling demonstrates to the client that flowing groundwater must be taken into account in the design of the frozen groundwater cutoff. Numerical modeling of the effects of groundwater flow saved the client millions of dollars in delays and redesign.

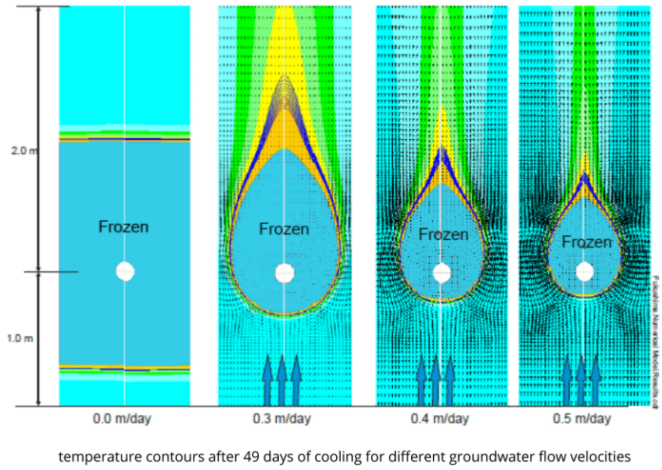


Figure 1: Numerical modeling of the effects of groundwater flow on growth of a freeze wall

Underground Storage of Compressed Gas

In the US, compressed natural gas has been stored in solution mined caverns in salt domes since the 1960's. Salt creep is a major factor which needs to be considered in the design and stability analysis of these underground openings. Numerical modeling is used to evaluate the stresses around the opening and predict the deformation of rock salt with use and time. When the gas pressure is cycled in an underground cavern, there are changes in temperature and stress that influence the creep rate. Under these conditions numerical modeling is the only method available to calculate the closure rates in the cavern walls. Numerical modeling provides the client with minimum and maximum cavern operating pressures and design parameters for spacing between multiple caverns. This benefits the project designers by allowing them to develop an optimized storage design based on site specific geotechnical engineering analysis and operational needs.

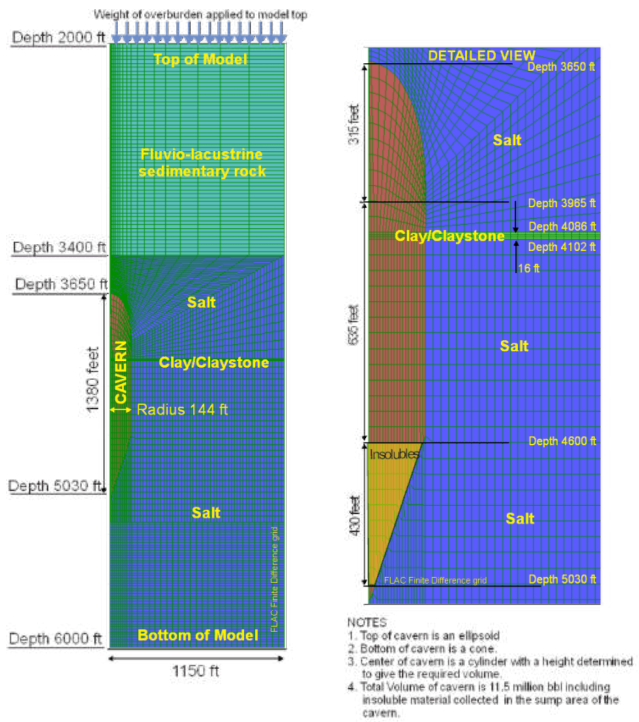


Figure 2: Numerical model of a deep cavern in salt for compressed air energy storage

Helping Design for a Complex Use Case

In the final example shown in Figure 3, a client wanted to develop design charts to promote the use of a proprietary retaining wall system comprised of steel soldier beams with soil mix lagging spanning between the beams. Traditional design methods for lagging are mostly empirical built up from experience. Numerical modeling provided the client with a parametric design chart used to promote the use of composite soil mix retaining wall structures. The numerical models also helped show that part of the load of the final structure could be supported by these retaining walls resulting in further efficiency of the design.

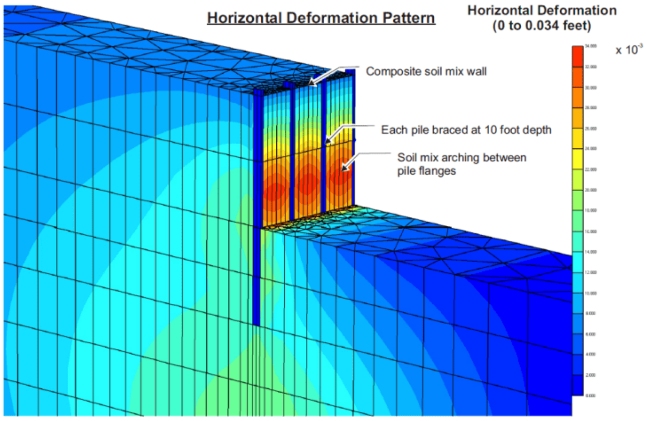


Figure 3: 3D numerical analysis of horizontal deformations in a composite soil mix retaining wall

In summary, numerical modeling is an important tool for analyzing complex geo-structural cases. It eliminates some of the conservatism used in regular design, reduces risk, and saves the client money. When analytical methods are not available, numerical modeling offers a great alternative to help develop safe designs without unnecessary conservatism.

Martin Hawkes is a Senior Geotechnical Engineer with a master's degree in Geotechnical Engineering from MIT. Mr. Hawkes has been with Geocomp for 27 years, involved with developing the early versions of iSiteCentral, developing the laboratory information database management system (LIMS) for GeoTesting Express, installing instrumentation, and geotechnical consulting. Martin provides a key role in numerical modeling with a unique skillset as a mentor for younger engineers.

(Martin Hawkes / Geocomp Blog, August 11, 2021, https://geocompgeotestingexpress-news.com/2021/08/11/the-value-of-numerical-modeling-for-geo-structural-engineering/)

Geographic-information-system-based topographic reconstruction and geomechanical modelling of the Köfels rockslide

Christian Zangerl, Annemarie Schneeberger, Georg Steiner, and Martin Mergili

Abstract

The Köfels rockslide in the Ötztal Valley (Tyrol, Austria) represents the largest known extremely rapid landslide in metamorphic rock masses in the Alps. Although many hypotheses for the trigger were discussed in the past, until now no scientifically proven trigger factor has been identified. This study provides new data about the (i) pre-failure and failure topography, (ii) failure volume and porosity of the sliding mass, and (iii) numerical models on initial deformation and failure mechanism, as well as shear strength properties of the basal shear zone obtained by back-calculations. Geographic information system (GIS) methods were used to reconstruct the slope topographies before, during and after the event. Comparing the resulting digital terrain models leads to volume estimates of the failure and deposition masses of 3100 and 4000 million m^3, respectively, and a sliding mass porosity of 26 %. For the 2D numerical investigation the distinct element method was applied to study the geomechanical characteristics of the initial failure process (i.e. model runs without a basal shear zone) and to determine the shear strength properties of the reconstructed basal shear zone. Based on numerous model runs by varying the block and joint input parameters, the failure process of the rock slope could be plausibly reconstructed; however, the exact geometry of the rockslide, especially in view of thickness, could not be fully reproduced. Our results suggest that both failure of rock blocks and shearing along dipping joints moderately to the east were responsible for the formation or the rockslide. The progressive failure process may have taken place by fracturing and loosening of the rock mass, advancing from shallow to deep-seated zones, especially by the development of internal shear zones, as well as localized domains of increased block failure. The simulations further highlighted the importance of considering the dominant structural features of the rock mass. Considering back-calculations of the strength properties, i.e. the friction angle of the basal shear zone, the results indicated that under no groundwater flow conditions, an exceptionally low friction angle of 21 to 24° or below is required to promote failure, depending on how much internal shearing of the sliding mass is allowed. Model runs considering groundwater flow resulted in approximately 6° higher back-calculated critical friction angles ranging from 27 to 30°. Such low friction angles of the basal failure zone are unexpected from a rock mechanical perspective for this strong rock, and groundwater flow, even if high water pressures are assumed, may not be able to trigger this rockslide. In addition, the rock mass properties needed to induce failure in the model runs if no basal shear zone was implemented are significantly lower than those which would be obtained by classical rock mechanical considerations. Additional conditioning and triggering factors such as the impact of earthquakes acting as precursors for progressive rock mass weakening may have been involved in causing this gigantic rockslide.

How to cite.

Zangerl, C., Schneeberger, A., Steiner, G., and Mergili, M.: Geographic-information-system-based topographic reconstruction and geomechanical modelling of the Köfels rockslide, Nat. Hazards Earth Syst. Sci., 21, 2461–2483, https://doi.org/10.5194/nhess-21-2461-2021, 2021.

1 Introduction

In mountain areas, life and property are often put at risk by landslide processes (e.g., Dai et al., 2002; Nadim et al., 2006; Margottini et al., 2013; Sassa et al., 2014). Rapid collapses of huge mountain slopes – and resulting process chains – have repeatedly evolved into catastrophic events (e.g., Evans and DeGraff, 2002; Govi et al., 2002; Genevois and Ghirotti, 2005; Evans et al., 2009a, b). An adequate understanding of the mechanisms of the initial failure and extremely rapid movement processes is one key for the implementation of effective risk reduction strategies. The analysis of past – even fossil – events may contribute to a better understanding of landslide processes and therefore help us to develop and to improve methods for hazard and risk mitigation (Kilburn and Pasuto, 2003).

Known as the largest landslide in metamorphic rock throughout the European Alps, the Köfels rockslide represents such a fossil landslide (see Sect. 2 for a detailed description). In contrast to numerous deep-seated rockslides in foliated metamorphic rocks characterized by movement rates of a few centimetres to decimetres per year and without indications of total slope failure (Zangerl et al., 2015), the Köfels rockslide is a prominent case study for a sudden slope failure with extremely rapid movement velocities. This can be clearly demonstrated by the occurrence of frictionites which were found at outcrops on the deposited sliding mass (Erismann et al., 1977). Even though this giant landslide has been the subject of numerous studies focussing on the genesis of the frictionites, age of the event, spatial distribution of the source area, volume of the rockslide mass and geomechanical aspects concerning the trigger and failure mechanisms (e.g., Pichler, 1863; Milton, 1964; Preuss, 1974, 1986; Erismann et al., 1977; Preuss et al., 1987; Erismann and Abele, 2001; Brückl et al., 2001, 2010; Brückl and Parotidis, 2001, 2005; von Poschinger, 2002; Sørensen and Bauer, 2003; Prager et al., 2009, Nicolussi et al., 2015), the conditioning and triggering factors of the Köfels rockslide still remain unknown and speculative.

Computer models focussing on the rockslide geometry and geomechanical processes may help to increase our understanding of the mechanisms of rock slope failure. Although models are always a rough simplification of reality, some are useful to explore specific aspects such as initial failure processes, slope deformations, rockslide volumes or critical values of geomechanical parameters at failure. In the context of this study two types of models, i.e. topographical and geomechanical models, are relevant. Brückl et al. (2001) were the first ones who reconstructed the 3D pre-failure topography and failure geometry of the Köfels rockslide on the basis of seismic measurements and terrain models, and they derived parameters such as failure and deposition volumes, porosity, the initial and average sliding angles, and the release of potential energy.

In our study we used new high-resolution (1 m raster data) ALS-based (airborne laser scanning) digital terrain models, new geological mapping data and pre-existing data from seismic measurements to re-build and re-analyse the pre- and post-failure topographies and geometries of the rock-slide. Based on this topographic reconstruction by using geographic information system (GIS) analysis methods, a geometrical and kinematical rockslide model was developed. Conclusions can be made about the failed and deposited volumes and consequently the change of rock mass porosity induced by the rapid sliding and fracturing and loosening processes.

Concerning geomechanics of the rockslide at initial failure state and movement, several attempts were made to investigate the mechanisms and to back-calculate rock mass properties. Erismann et al. (1977) developed a kinematic and thermodynamic model to explain the energy release necessary for the formation of the frictionites that were found at the Köfels site (see Sect. 2). Brückl and Parotidis (2001) set up a 2D elastic and elasto-plastic continuum model to estimate the geomechanical rock mass properties of the Köfels rockslide. In their approach they applied the 2D finite element method to explore the initial phase of the failure process by studying the creeping and strength degradation of the rock mass. The model suggests that the Köfels rockslide was formed due to the progressively weakening strength of the rock mass, which was initiated at the foot of the slope and propagated uphill. Furthermore, the model calculations determined surprisingly low friction angles of the rock mass, ranging between 20 and 24°, to induce slope failure. In another approach, Brückl and Parotidis (2005) proposed a model with focus on time-dependent strength degradation and slope failure under low stress regimes such as rock mass creep and subcritical crack growth. They suggest that subcritical crack growth is a primary geomechanical process which, after glacier retreat, is able to explain the considerable rock mass strength weakening needed for failure.

However, the extraordinary low-strength properties of the rock mass that were back-calculated by 2D continuum approaches for the failure state raise questions:

- Can we plausibly reconstruct the topography to provide a realistic pre-failure topography for the geomechanical modelling?
- How could the initial failure and slope deformation process have taken place?
- How can the strength of such a strong granitic rock mass reduce to such small values needed to promote failure?
- Are there any structural particularities in the Köfels rockslide area that may have contributed to slope failure and what is the influence of the pre-existing fracture network?
- Why do we observe only one such giant and extremely rapid rockslide characterized by a flat to moderately dipping failure surface in the Ötztal–Stubai crystalline basement?

Given that, so far, only 2D continuum models have been applied to investigate the failure mechanisms of the Köfels rockslide, we believe that, though representing a valid approach, additional types of models, e.g. discontinuum models, are useful to adequately capture the complexity of the phenomenon. Discontinuum models such as the distinct element method have the advantage that the geometry of the rockslide mass and the discrete basal shear zone can be implemented directly based on geometrical and structural field observations and GIS reconstructions. Geomechanically, the basal shear zone, i.e. stepped rupture surface, can be considered in the model as a discrete narrow zone. In order to fill this gap, we set up a 2D discontinuum model of the Köfels rockslide based on the geometry obtained by the topographic reconstruction and by applying the Universal Distinct Element Code (UDEC; Itasca, 2020). The initial failure process was studied by considering the main structural characteristics based on geological field surveys. The aim was to investigate how the rockslide geometry and the basal shear surface (zone) was formed during the initial failure process. In addition, back-calculations of the critical angle of friction along the basal shear zone assuming no groundwater flow conditions and groundwater flow are conducted under quasi-static conditions. These back-calculations were done to determine the shear strength properties, i.e. friction angle and cohesion, of the predefined and field-based basal shear zone needed to promote failure. The models were performed to explore the influence of fracture water pressure in the rock mass and basal shear zone resulting from high groundwater levels for provoking this giant landslide.

The numerical modelling study was supplemented by a geological field survey searching for instability-relevant discontinuities of different origin and scale. This was done to investigate the impact of discontinuities which ideally are dipping moderately towards the east, acting as weakness zones and thus reducing the overall rock mass strength. Particular focus was given to the identification of low-strength brittle fault zones composed of gouges and breccia characterized by a high persistence.

Next, we introduce the study area, the Köfels rockslide (Sect. 2). Then, we explain the methods applied for the topographic reconstruction and geomechanical modelling (Sect. 3). We present (Sect. 4) and discuss (Sect. 5) the results before concluding with the key messages of this study (Sect. 6).

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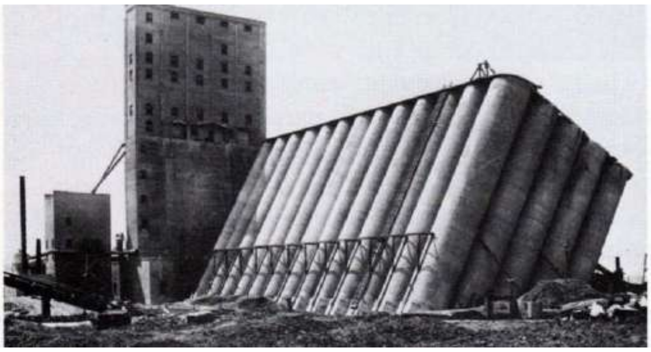
(European Science Union, Natural Hazards and Earth System Sciences, Volume 21, issue 8, NHESS, 21, 2461–2483, 2021 https://nhess.copernicus.org/articles/21/2461/2021/)

Transcona Grain Elevator Failure: Lessons on Bearing Capacity



The Canadian Pacific Railway Company in the year 1913 constructed the Transcona grain elevators of about 36400 m^3 capacity to provide relief for the Winnipeg Yards during the months of peak grain shipment. The structure consisted of a reinforced concrete work-house, and an adjoining bin-house, which contained five rows of 13 bins, each 28 m in height and 4.4 m in diameter.

The bins were based on a concrete structure containing belt conveyors supported by a reinforced concrete shallow raft foundation (Puzrin et al, 2010). The reinforced concrete raft foundation was 600 mm thick, with dimensions of 23.5 x 59.5 m.

Excavation for the construction of the elevator foundations started in 1911, and the first 1.5m depth of soil at the site was rather soft. Beyond the soft clay layer was a relatively stiff blue clay, typical for that area, and locally known as the "blue gumbo".

According to literature cited by Puzrin et al (2010), no borings or extensive geotechnical investigations were carried out prior to the construction. This is not a surprise, given the level of technology and knowledge about soil engineering at that time. However, an in-situ bearing capacity test (test loading applied using a specially constructed wooden framework) was performed at a depth of 3.7 m.

According to the literature cited by Puzrin et al (2010), the plate load test result indicated that the soil was capable of bearing a uniformly distributed load of at least 400 kPa. The maximum foundation pressure from the bins at maximum load was not expected to exceed 300 kPa, therefore the tests appeared satisfactory to the engineers. Furthermore, they assumed that the "blue gumbo" at the site had similar characteristics and a depth to that on which similar raft foundations of many heavy structures had been founded in the vicinity of Winnipeg. This eventually turned out not to be so.

After the structure was completed, the filling was begun and grain was distributed uniformly between the bins. On October 18, 1913, after the elevator was loaded to 87.5% of its capacity, settlement of the bin-house was noted. Within an hour, the settlement had increased uniformly to about 300 mm following by a tilt towards the west, which continued for almost 24 hours until it reached an inclination of almost 27 degrees (Puzrin et al, 2010).

Several wash-borings were made immediately after the failure, showing that the elevator was underlain by rather uniform deposits of clay. This finding was in agreement with the geological history of the area, according to which extensive fine-grained sediments were deposited in the waters of the glacial Lake Agassiz which came into being when the Wisconsin ice-sheet blocked the region's northern outlet.

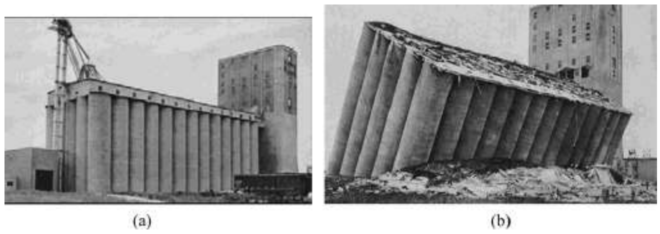


Fig 1: Transcona grain elevator (a) Before failure (b) After failure

It was noted that no laboratory test was carried out on the samples collected during the wash borings, but classification was done based on visual observation. The wash-borings, therefore, confirmed the designers' assumptions of uniform clay layer, and the failure of the Transcona Grain Elevator remained a mystery for another 40 years.

It was thought that, if the smaller-scale plate loading tests predicted a safety factor of more than 1.3 (400/300 = 1.33), and the soil profile is homogeneous, how could the foundation fail? The answer to this question was given by Peck and Bryant (1953) who, in 1951 (38 years later), made two additional borings, far enough from the zone of failure to be in material unaffected by the displacements (Puzrin et al, 2010).

They obtained undisturbed soil samples and performed unconfined compression strength tests (triaxial shear tests with zero confining stress), which produced some eye-opening results shown in Fig 2.

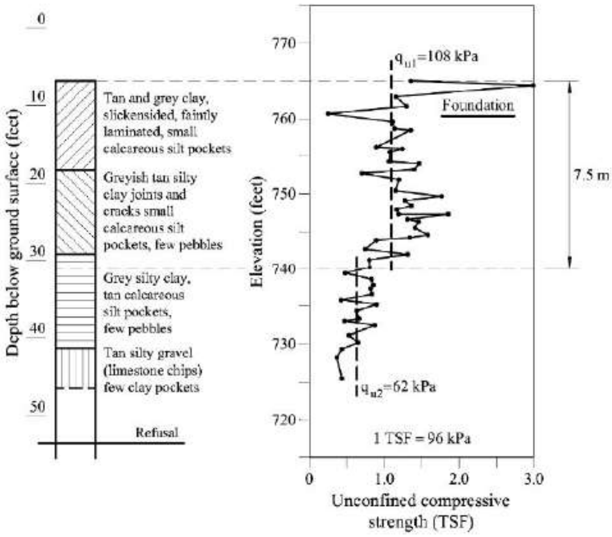


Fig 2: Soil profile below the elevator (after Peck and Bryant, 1953) (a) classification; (b) unconfined compression strength

On observation of the unconfined compressive strength (q_u) result of the site, there are two easily distinguishable layers (Fig. bb). The upper one, a 7.5 m thick stiff clay layer with q_u = 108 kPa (undrained shear strength $c_u = q_u/2$ = 54 kPa), appears to be resting on a softer clay layer with q_u = 62 kPa (c_u = 31 kPa). This finding suggests that the elevator failure was most likely caused by the insufficient bearing capacity of its foundation.

In a bearing capacity failure, a failure mechanism is formed below the foundation (Fig. 3b). The settlement takes place much faster and without decrease of the soil volume. Therefore, the displaced soil has to find itself an exit, causing a ground heave in the vicinity of the structure. This ground heave is a distinctive feature of the failure of the Transcona Grain Elevator (Puzrin et al, 2010).

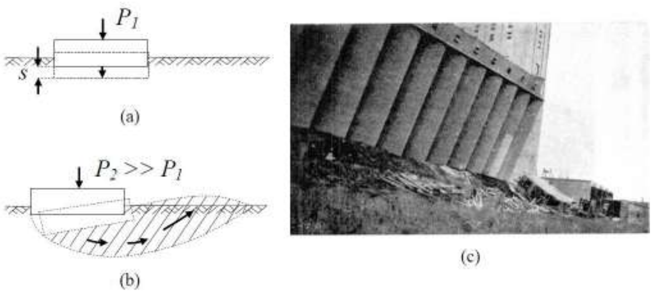


Fig 3: Bearing capacity failure: (a) settlement; (b) failure; (c) the ground heave (Puzrin et al, 2010)

According to (Puzrin et al, 2010), the particular problem of the Transcona Grain Elevator was that the failure mechanisms of the plate loading tests were apparently confined to the upper stiffer clay layer, due to the relatively small size of the plates. The elevator foundation, however, developed a much deeper failure mechanism which entered the weaker clay layer, significantly reducing the bearing capacity.

This led the researchers to consider the two-layer model and other bearing capacity theories that are adequate to describe the situation on the site. Details of this can be found in Puzrin et al, (2010).

It was observed that the true failure contact pressure was 293 kPa. In the original design, it was assumed that the soil profile was homogeneous with the properties of the stiff upper layer u_{c1} = 54 kPa. In this case, the bearing capacity of the foundation was calculated as 386 kPa (applying the appropriate bearing capacity, shape, and depth correction factors). This was found to be close to the 400 kPa obtained from the plate load tests.

Note that if the soil was homogeneous but with the properties of the weaker lower layer (u_{c2} = 31 kPa), the resulting bearing capacity would be 251 kPa. If this value was available to designers, the result would actually not be that bad: not only the elevator would not fail, it would not even be too much overdesigned.

A more sophisticated analysis, based on a two-layer model, should produce more accurate predictions. First, the reseachers followed Peck and Bryant (1953) and used the approximate method based on the Prandtl solution using a weighted average of the undrained shear strength. This gave a bearing capacity of 321 kPa which is 10% larger than the failure pressure. While the Prandtl solution for a homogeneous soil is the exact solution, in the two-layer approximation, it was observed that it is not only inaccurate, but it is also not conservative and could lead to failure.

The scoop mechanism, in contrast, provides a remarkably good bearing capacity estimate of 297 kPa. Being an upper bound, this value, as expected, is higher than the true failure pressure of 293 kPa, but only marginally. It would provide an excellent estimate for the design of the elevator if only the Soil Mechanics was more mature in those days and the soil properties were properly determined.

Source:
The information in this article was majorly obtained from: Puzrin A. M., Alonso E.E., Pinyol N. M. (2010): Geomechanics of Failures. Springer. DOI 10.1007/978-90-481-3531-8, https://link.springer.com/chapter/10.1007/978-90-481-3531-8_4

(Ubani Obinna / STRUCTVILLE, April 11, 2021, https://structville.com/2021/04/transcona-grain-elevator-failure-lessons-on-bearing-capacity.html)

ΝΕΑ ΑΠΟ ΤΙΣ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

International Society for Soil Mechanics and Geotechnical Engineering

ISSMGE News & Information Circular August 2021
https://www.issmge.org/news/news-and-information-circular-august-2021

1. ELECTION OF ISSMGE PRESIDENT 2022-2026

As a consequence of the 20ICSMGE being pushed back to May 2022, and in accordance with the Statutes and Bylaws, the deadline for receiving nominations for the next ISSMGE President has been extended to 30th January 2022.

2. 20ICSMGE / 7iYGEC NEW DATES MAY 2022

New dates have been confirmed for the conferences in Sydney as follows;
7iYGEC - Friday 29 April - Sunday 1 May 2022
20ICSMGE - Sunday 1 May - Thursday 5 May 2022.

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

3. TIME CAPSULE PROJECT (TCP)

You may already know that an ISSMGE Blog section has been launched as part of the ISSMGE Time Capsule Project (https://www.issmge.org/the-society/time-capsule), the idea being to stimulate personal consideration on the practice of Geotechnical Engineering. Contributions of 200-400 words on any topic that will generate debate within the Geotechnical Engineering profession are encouraged, and may be submitted via the website. For further information, examples of current and upcoming articles, and instructions on submission, please go to the TCP pages on the ISSMGE site https://www.issmge.org/news/tcp-blog-posts

4. NEW WEBINAR

New TC103 Lecture "Numerical Simulations by Energy Piles" by Prof. McCartney, is a new webinar now available from the ISSMGE website.

5. 3rd HUTCHINSON LECTURE - 3rd JTC WORKSHOP NORWAY, 2022 CALL FOR PROPOSALS

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

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

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

6. BULLETIN

The latest edition of the ISSMGE Bulletin (Volume 15, Issue 3, June 2021) is available from the website https://www.issmge.org/publications/issmge-bulletin/vol-15-issue-3-june-2021

7. ISSMGE FOUNDATION

The next deadline for receipt of applications for awards from the ISSMGE Foundation is the 30th September 2021. Click here for further information on the ISSMGE Foundation.

8. CONFERENCES

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

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

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

ISSMGE Events

6TH INTERNATIONAL CONFERENCE ON GEOTECHNICAL AND GEOPHYSICAL SITE CHARACTERIZATION - 26-09-2021 - 29-09-2021 Budapest Congress Center, Budapest, Hungary; Language: English; Organiser: Hungarian Geotechnical Society; Contact person: Tamás Huszák; Address: Muegyetem rkp. 3.;Email: info@isc6.org; Website: http://isc6.org

SECOND GENERATION OF EUROCODE 7 – IMPROVEMENTS AND CHALLENGES - 28-09-2021 - 29-09-2021 Online, Netherlands; Language: English; Organiser: ISSMGE ERTC10; Contact person: Georgios Katsigiannis (Chair of ISSMGE ERTC10); Email: georgios.katsigiannis@ekfb.com; Website: https://second-generation-of-eurocode7.nen-evenementen.nl/

17TH DANUBE - EUROPEAN CONFERENCE ON GEOTECHNICAL ENGINEERING - DATES TO BE CONFIRMED Ramada Parc, Bucharest, Romania- September 2023); Language: English; Organiser: Romanian Society for Geotechnical and Foundation Engineering; Contact person: Ernest

Olinic; Address: Bvd. Lacul Tei 124; Email: srgf@utcb.ro; Website: http://www.17decge.ro

New TC304 Lecture "How to Perform Reliability Analyses on a Spreadsheet" by Dr. Lei Wang

Watch Lecture on ISSMGE Virtual University

How to Perform Reliability Analyses on a Spreadsheet - Part I:

This video is a part of a series of short educational videos on geotechnical reliability and risk initiated by ISSMGE TC304. This video provides an introduction about how to perform the reliability analyses using the first-order reliability method (FORM) implemented on a spreadsheet. It starts with the discussion of basic FORM algorithm, followed by a case study of a real-world supported excavation problem illustrated with the step-by-step implementations on a spreadsheet. The video is supposed to be educational while related references are provided for interested audiences.

How to Perform Reliability Analyses on a Spreadsheet - Part II:

This video is a part of a series of short educational videos on geotechnical reliability and risk initiated by ISSMGE TC304. This video provides an introduction about how to perform the advanced probabilistic analyses including probabilistic inverse analysis and robust geotechnical design on a spreadsheet. It starts with the principles of probabilistic inverse analysis and its application in the supported excavation problem for updating the excavation-induced ground responses. Then the robust geotechnical design methodology is introduced using the drilled shaft design in clay as an example. The video is supposed to be educational while related references are provided for interested audiences.

The 1st ERTC10 Seminar: Second Generation of Eurocode 7 - Improvements and Challenges

The first ERTC10 Seminar on "**Second Generation of Eurocode 7** - Improvements and Challenges" will be held online on: **Tuesday 28th September 2021 at 15:00-17:00 (CEST)**

This event is organized together with CEN TC250/SC7 and with the support from NEN (Dutch standardization organization). Its aim is to disseminate the knowledge about the changes and upgrades introduced in the currently prepared second generation of Eurocode 7. The new version of the code will be published in upcoming years and it will be used as a reference document for thousands of engineers in Europe and outside of it.

The first **seminar will include three main lectures** covering the general aspects of the new version of the Eurocode 7. They will be delivered by Adriaan van Seters (SC7 Chair), Gunilla Franzén (SC7 Vice-Chair) and Jose Estaire (SC7 member). During a break between lectures, an **interactive session** will be organized to get a feedback from people attending the live event.

We are looking forward to get your opinion about the new version of the code. Please register as soon as possible as the maximum number of attendees will be limited.

More information at:

https://www.issmge.org/events/second-generation-of-eurocode-7-improvements-and-challenges0

Registration (free) and detailed information at:

https://second-generation-of-eurocode7.nen-evenementen.nl/

15-min short videos coordinated by TC304 Young Group (Andy Leung, Zijun Cao & Lei Wang)

TC304 has contributed the following 15-min short videos to ISSMGE Virtual University (coordinated by TC304 Young Group: Andy Leung, Zijun Cao & Lei Wang)

How to characterize site/model uncertainty (Zijun Cao) http://virtualuniversity.issmge.org/courses/course-v1:ISSMGE+TC304-103+2020/about

How to estimate characteristic values for design (Yu Wang) http://virtualuniversity.issmge.org/courses/course-v1:ISSMGE+TC304-101+2019/about

How to perform reliability analyses on a spreadsheet (Lei Wang) http://virtualuniversity.issmge.org/courses/course-v1:ISSMGE+TC304-104+2021/about

Insights from geotechnical reliability-based design (BK Low) http://virtualuniversity.issmge.org/courses/course-v1:ISSMGE+TC304-102+2020/about

Besides, Marco Uzielli produced a 90-min ISSMGE webinar in 2017 on Risk and Geotechnical Engineering https://www.issmge.org/education/recorded-webinars/risk-and-geotechnical-engineering

New Lecture "Geosynthetics in Roadway Applications" by Prof. Jorge G. Zornberg

Watch Lecture on ISSMGE Virtual University (Chapter 5 - Part of Geosynthetics Course)

Geosynthetics have been extensively used to fulfill many functions in multiple roadway applications. Geotextiles (woven and non-woven), geogrids (biaxial and multiaxial), and geocells are among the several geosynthetic products that have been successfully adopted to fulfill the functions of separation, filtration, reinforcement, stiffening, infiltration barrier, and drainage. Geosynthetics have been used in roadway applications such as mitigation of reflective cracking in structural asphalt overlays, stabilization of unbound aggregate layers, reduction of layer intermixing, reduction of moisture in structural layers, stabilization of soft subgrades, and mitigation of distress induced by shrink/swell subgrades. This presentation provides a framework to categorize the multiple objectives, functions, and mechanisms involved in the different roadway applications. It also highlights the significant benefits to roadway performance that can be brought with the use of geosynthetics in their design.

Jorge G. Zornberg, Ph.D., P.E., F.ASCE, Brunswick-Abernathy Regents Professor, *The University of Texas at Austin*

Prof. Zornberg has over 30 years experience in practice and research in geotechnical and geosynthetics engineering. His research focuses on transportation geotechnics, geosynthetics, unsaturated soils, expansive clays and environmental geotechnics. He served as president of the *International Geosynthetics Society* (IGS). He has authored over 450 technical publications, written several book chapters, and been awarded three patents. Prof. Zornberg received numerous prestigious awards, including the *Presidential Early Career Award for Scientists and Engineers* (PECASE) awarded by the President of the United States. The IGS recently established the Zornberg Lecture Award in recognition of his contributions to the geosynthetics discipline.

Vol. 6, Issue 2 of the ISSMGE IJGCH has been released!

We are pleased to announce the Issue #2 of Volume #6 of the International Journal of Geoengineering Case Histories, an official Journal of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE).

Papers published in this refereed journal are freely available in color and are accompanied by databases that include the electronic data presented in the paper as well as additional figures (as necessary). The locations of the case histories are also positioned in the IJGCH Geographic Database.

International Symposium co-organized by TC303 in Chongqing

Professor Hanlong Liu gave welcome Speech

Professor Zhongqiang Liu gave a speech on Risk assessment of quick clay landslides in Norway

Professor Zhongqiang Liu from NGI, Professor Liming Zhang from HKUST, Dr ATM Shakhawat Hossain, Dr. Zhu Chuanbin, Prof Qiushi Chen, Dr Kieron Norris gave the online TC-relevant speeches titled Risk Assessment of Quick Clay Landslides in Norway Long-distance landslide disaster chain on Sichuan-Tibet Railway Climate Variability and Its Impact On the Landslide Hazards In the Rohingya Refugee Camps, Cox'sbazar, Bangladesh for Sustainable Community Living How Well Can We Predict Earthquake Site Response So Far? Data-driven assessment of site response at liquefiable sites From Risk to Resilience: Securing Data Centres through Effective Due Diligence, respectively.

Professor Limin Zhang gave a speech on Long-distance landslide disaster chain on Sichuan-Tibet Railway

New Lecture "Stress-strain behaviour of geomaterials (mainly granular materials) from elastic behaviour to shear banding" by Prof. Fumio Tatsuoka

The lecture is part of the newly formed "Soil Behaviour" course.

Watch Soil Behaviour course on ISSMGE Virtual University

This course on **Stress-strain behaviour of geomaterials (mainly granular materials) from elastic behaviour to shear banding** is based on the lectures of the presenter for graduate students at University of Tokyo and Tokyo University of Science. The objective of the course is to introduce the major characteristic features of the stress-strain behaviour of geomaterials, mainly granular materials and also partially clays, cement-mixed soils and natural soft rocks. The contents of this course are explained only to a very limited extent in ordinary under-graduate courses, despite that it is required to properly understand them to deal with many geotechnical engineering problems/issues.

The course consists of the following six lectures covering the stress-strain behaviours in a very wide strain range.

The first lecture introduces the contents of the second to sixth lectures. It is explained that, in this course, it is attempted to bridge a gap in the stress-strain behaviour of geomaterials between the basic soil mechanics and the SOA geotechnical engineering practice.

The second lecture presents **the stress-strain behaviour at very small strains**, say lower than 0.001 %, which is essentially reversible and rate-independent (i.e., elastic). Several full-scale geotechnical case histories with data from laboratory and field measurements are presented. It is shown that the elastic properties measured by dynamic loading tests, wave propagation tests and static stress-strain tests (with local strain measurements) are essentially the same. A hypo-elasticity model in which the elastic properties are stress state-dependent and could be inherently anisotropic is explained. It is shown that the elastic properties from field shear wave velocities become the basis for non-linear FEM analysis in many geotechnical boundary value problems.

The third lecture presents **the dilatancy characteristics** in drained shear and their effects on undrained shear behaviour. The Rowes stress-dilatancy equation in monotonic loading and its extension to cyclic loading are explained. It is shown that, controlled by the dilatancy characteristics, the undrained stress-strain behaviour of saturated soil becomes highly dependent on the compacted dry density and this trend is stronger in cyclic loading than in monotonic loading. The importance of this feature in the seismic design of soil structures and natural slopes is explained.

The fourth lecture presents **the peak strength** of granular materials. **The effects of confining pressure** on the $_0$ value from a very low value (2 kPa) to relatively high values were extremely carefully evaluated by triaxial and plane strain compression tests and torsional shear tests. It is also shown that **the inherent anisotropy** could be equally important as the effects of void ratio. The relationship between the strengths by ordinary triaxial compression test and the simple/direct shear test is explained taking into account the effects of the intermediate principal stress, the strength anisotropy and the fact that the shear plane in the simple/direct shear test deviates from the plane of maximum stress obliquity in a specific way.

The fifth lecture addresses **the shear banding**, which starts immediately before the peak stress state and develops in the post-peak strain-softening regime. Based on local strain fields carefully measured in a comprehensive series of plane strain compression tests, it is shown that the thickness of shear band is proportional to the mean particle size D_{50} (about $10D_{50}$) and the local shear strain in a shear band has become about 80 % when arriving at the residual stress state, where the shear stress is kept essentially constant irrespective of shear strain. As a result, the local shear deformation of shear band required to arrive at the residual stress state increases with an increase in D_{50}. Then, based on the results of a comprehensive series of plane strain model tests in 1g with various footing sizes up to 0.5 m and centrifuge tests with small footing sizes, it is shown that the bearing capacity of strip footing on sand increases with an increase in the particle size relative to the footing size under the same pressure level. So, a centrifuge test on a small-scaled footing on a sand simulates the behaviour of a large prototype footing on a gravel. It is also shown that these test results can be correctly simulated by numerical analysis only when taking into account the particle size effects on post-peak strain softening associated with shear banding, as well as the effects of confining pressure on the $_0$ value and strength anisotropy and others.

In the sixth lecture, two different time effects: i.e., **rate-dependent stress-strain behaviour and ageing effects**, are explained based on results from comprehensive series of stress-strain tests. With respect to the rate effects, it is shown that, with a decrease in the inter-particle stability by bounding or unbound-locking and with an increase in its damage by straining, the strength increase with an increase in the constant strain rate becomes weaker, while it could become even negative. As a result, with an increase in the constant strain rate, the strength increases with well-bound geomaterials while decreases with unbound poorly graded round granular materials. These phenomena are complicated but systematic, and it is indispensable to take into account them when analysing the data from laboratory stress-strain tests and field observations. It is also shown that, with bound geomaterials with developing ageing effects, such as relatively young cement-mixed soils, during sustained loading, creep deformation and ageing effects take place simultaneously, both resulting into the development of yield stress. Then, upon the restart of loading, nearly elastic behaviour is exhibited for some large stress range. All these phenomena of rate effects, including creep deformation and stress relaxation, and ageing effects are explained in a unified framework and simulated by a non-linear three-component model.

Rocscience Online Course - 2D & 3D Slope Stability Analysis

Description:

Join us in October 2021 for an online course on 2D & 3D Slope Stability Analysis. The course will be spread across 2 sessions, with 4.5 hours each day.

Link for the registration:

https://www.rocscience.com/about/news-events/course-2d-3d-slope-stability-analysis-2021

Data/Time:

October 26 - 27, 2021, 10 AM - 2:30 PM Eastern Standard Time

Collapse of Fujinuma Dam by the 2011 Great East Japan Earthquake and its reconstruction

View Course Enroll

View Course, allows you to view course without logging in. Enroll, allows you to track your course history while logged in.

About This Course

Collapse of Fujinuma Dam by the 2011 Great East Japan Earthquake and its reconstruction by Prof.Fumio Tatsuoka and Dr.Antoine Duttine.

News

https://www.isrm.net

Presidential election for the 2023-2027 term of office

2021-08-04

The election of the ISRM President for the 2023-2027 term of office 2023-2027 will take place during the ISRM Council Meeting on 17 November 2021. The successful candidate will become the President-elect for the two years until 2023.

The candidates are Anna Maria Ferrero, nominated by Italy; Jian Zhao, nominated by Australia; Seokwon Jeon, nominated by Korea.

The candidates were asked to provide videos of their background and intentions. Click here to watch these videos on the ISRM website, where the candidates' nomination documents are also available.

35th ISRM Online Lecture by Dr. Christine Detournay on September 16th

2021-08-08

The 35th Online Lecture with the title "Findings from Numerical Modeling at the Site of a High Dam on the Jinsha River" by Dr. Christine Detournay, Principal Engineer at the Itasca Consulting Group, will broadcast in September 16th, 10 A.M. GMT. Find more information in this link.

Video of the Suggested Method on Needle Penetration Test

2021-08-11

A video of the Suggested Method on Needle Penetration Test has been recorded from experiments conducted in the Laboratorio de Mecánica de Suelos e Rocas of the Alicante University. This is the tenth in the Suggested Method explanatory videos series, recorded in cooperation between several universities and Rock Mechanics Laboratories and the ISRM Commissions on Testing Methods and on Education. Visit this link to watch the video.

Mongolian was added to the ISRM Rock Mechanics and Rock Engineering Glossary

2021-08-29

Mongolian is now available at the ISRM Rock Mechanics and Rock Engineering Glossary. You can now browse or search through more than one thousand terms in 18 different languages.

Click to open the Glossary, under Products and Publications. https://isrm.net/page/show/138?tab=1189

Scooped by ITA-AITES #49, 17 August 2021

'More than a day to bore through 10cm of rock': Making Stage 2 of the Thomson-East Coast Line a reality | Singapore

Massive underground shopping center planned beneath the canal district | China

Crossrail | Proposals to extend Elizabeth line to Ebbsfleet whittled down to three viable options | UK

No. 10 tunnel of Jakarta-Bandung high speed railway completed | Indonesia

Bulgaria begins construction of Balkan's longest dual-bore tunnel

New tunnel to be built on TransSiberian railway | Russia

Tunnelling machine to go to work beneath Belfast streets | UK

Tunnel boring begins in Ballard for Ship Canal Water Quality project | United States of America

Etihad Rail's mighty mole bores through Hajar mountains to pave way for tracks | UAE

West Gate tunnel project blows out by $3.3 billion as Transurban scraps estimated completion date | Australia

Deqing tunnel of Guiyang-Nanning high-speed railway drilled through | China

Stonehenge tunnel plans remain in motion despite protests | UK

Scooped by ITA-AITES #50, 31 August 2021

Undersea tunnel planned to release treated water | Japan

Who is in favour or against the Malta-Gozo tunnel project?

Dubai Metro's biggest underground station set to open on Wednesday | United Arab Emirates

Kolkata to Get 3 underground tunnels as metro rail network expands in City | India

Budapest Metro marks 125 years as world's 2nd oldest underground railway | Hungary

Metro Farm – Seoul | South Korea

Scottish isles 'would benefit' from Faroes-style tunnels | UK

Systra to design Bogotá's second metro line | Colombia

TBM named after Olympian tunnelling under Yarra | Australia

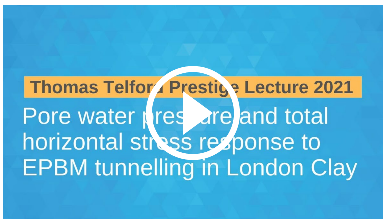
Eight-lane immersed-tube tunnel set to replace aging Massey Tunnel | Canada

Have you read our top 10 papers?

Whether you're interested in improving the carbon footprint of the construction industry or finding out the latest developments in geotechnical research, we have a paper for you! All **free to read** until the end of September.

Read them all now

Popular free webinar recordings



Measured ground response to EPBM tunnelling in London Clay

Designing a safer built environment

10 recommended reads

We recommend 10 top books that will count towards your professional development.

Take a look

International Geosynthetics Society

www.geosyntheticssociety.org/news

My Engineer Life With… Alex De Guzman

In our continuing series with engineers at the start of their careers we speak to Alex de Guzman. Alex works for IGS corporate member Tonkin + Taylor in New Zealand. AUGUST 3, 2021

GeoAsia 7 Abstracts Deadline Extended! Submit Your Abstracts Now!

Considering the overwhelming requests from several organizations, the deadline for GeoAsia 7 Abstract Submission has been extended from July 31 to August 31 (00:00 GMT + 8). AUGUST 9, 2021

IGS To Launch New Website

The IGS is delighted to announce its soon-to-launch new website! With a more modern look and functionality, the revamped site aims to give users greater access to a range of … AUGUST 9, 2021

Fellowships for Graduate Students from the Geosynthetic Institute

Fellowships for Graduate Students Established: Summer 2008 by action of its Officers and the GSI Board of Directors Funding: $5,000 per year to student's academic institution This merit-based award … AUGUST 10, 2021

Portuguese Webinar: 'Sustainable Solutions in Geosynthetic-Reinforced Soils'

Portuguese speakers are set to enjoy a webinar covering 'Sustainable Solutions in Geosynthetic Reinforced Soils' later this month. The IGS Pan American Committee is hosting this event in Portuguese, … AUGUST 19, 2021

IGS Chile Hosts First Members' Assembly

Exciting webinar topics and plans for the rest of 2021 were shared at IGS Chile's first members' meeting. Participants gathered virtually to hear what the chapter had in store and … AUGUST 23, 2021

Book Now For IGS 'Big Four' Conferences

Get a front-row seat on the latest developments in geosynthetics by signing up for one of the IGS's major conferences. Face-to-face participation returns to the conference calendar as organizers continue … AUGUST 26, 2021

TC-B Interface Shear Testing Webinar

Improve your understanding of interface shear testing at a talk by geosynthetics testing expert Gary T. Torosian. Mr Torosian will speak on 'Successfully specifying, performing and interpreting interface shear tests' … AUGUST 30, 2021

IGS Opens Call to Host 13th ICG in 2026

Dear IGS Colleagues, Today we are opening the call for bids to host the 13th International Conference on Geosynthetics (ICG) in 2026. Could your Chapter or organization be the successful bidder to … AUGUST 31, 2021

13th ICG 2026 - CALL FOR BIDS

Dear IGS Colleagues,

Today we are opening the call for bids to host the 13th International Conference on Geosynthetics (ICG) in 2026.

Could your Chapter or organization be the successful bidder to run one of the most prestigious events in the geosynthetics calendar?

We want to encourage as many excellent bids as possible, and to ensure a fair and transparent process. For this reason, we are also publishing a new guide to help you prepare your submission.

ICGs take place every four years, dating back to Paris, France, in 1977. Since then, host countries have ranged across the globe from Singapore to Brazil, from the USA to Japan, and many others. The IGS has been proud to support all ICGs since 1983.

Planning is already well underway for the 12th ICG – postponed from 2022 because of the pandemic – in September 2023 in Rome, hosted by the Italian Chapter of the IGS. We now want to find the hosts for the next ICG in 2026.

Our vibrant new bidding guide published today explains the history of the ICG, with contributions from geosynthetics pioneer J.P. Giroud and past ICG hosts on why you should bid. It sets out key dates and resources to help you put together a winning proposal.

Final bids must be received no later than 31 January 2022, and the winner will be chosen during a meeting of the IGS Council in Taiwan during GeoAsia7 in April. Interested parties should contact us as soon as possible so we can help you through the bidding process.

We look forward to hearing from you.

Good luck!

Chungsik Yoo

Chungsik Yoo, IGS President

Download the ICG Bid Guide **HERE**.

For more about the 12th ICG in Rome, Italy, on September 18-22, 2023, click **HERE**.

☙ ❧

Geo-Institute of ASCE

Mon, October 4, 2021 Terzaghi Day 2021

Every year on or around the birthday of Karl von Terzaghi, the Geo-Institute hosts Terzaghi Day, a celebration of the life and legacy of Karl Terzaghi. This year, join us October 4 for a conversation with Sergei Terzaghi of Arup as he reflects on his career and how Karl Terzaghi's work influenced him. And yes, he is Karl Terzaghi's grandson.

☙ ❧

Advances in Subsurface Mechanics for Energy and Environment (ASMEE) – 2021

The Center of Excellence on Subsurface Mechanics and Geo-Energy at the Indian Institute of Technology Madras is delighted to present a summer webinar series titled Advances in Subsurface Mechanics for Energy and Environment – 2021 (ASMEE – 2021). The webinar series will be held on Fridays in the months of July – September 2021.

The webinars will host leading researchers from academia and industry to discuss pioneering research in the broad area of subsurface mechanics. The choice of topics is diverse and is expected to include experimental and computational geomechanics, multiphase flow and reactive transport modeling, subsurface characterisation, geochemistry, and their applications in oil & gas and geothermal energy industries.

The talks are open to all; however, registration is mandatory. Details of each presentation will be sent one week prior to all registered participants.

July-September 2021

Register Online: https://civil.iitm.ac.in/asmee/register
E-mail: smge@civil.iitm.ac.in

☙ ❧

www.age-rp.com/home

From its inception as an academic subject, Geotechnical Engineering education has drawn inspiration from the experience of the practicing engineers and has developed further pivoted on the outputs of the cutting edge research performed at academic institutions. Derived from elements borrowed from geology, soil science, agronomy, and engineering, it is now considered as a specialised subject. However, it continues to push the boundaries on the fronts of several emerging topics such as geoengineering implications of bio-mediated soil processes, mechanics of unsaturated soils, computational geomechanics, usage of artificial intelligence techniques, non-invasive geomaterial characterisation, etc. From a scholastic perspective, there has been notable advancement in the theoretical aspects of Geotechnical Engineering. Nonetheless, practitioners tend to rely on transferable technologies, and follow established developments that are best suited to the field applications. The discipline has rightly been described as a ***Scientific Art***, where a strong linkage between research and practice is imperative for its further advancement. It is envisaged that, with growing concerns on depletion of natural resources, environmental degradation and in overall sustainable development, Geotechnical Engineering is going to play a crucial role as an interface between the humanity and mother earth.

This lecture series is aimed at coupling the learnings from academia and industry on several key topics in the discipline of Geotechnical Engineering. There will be two talks on each lecture: one from an academician and one from a practitioner. The mode of delivery of the lectures is online to ensure a better reach. **The lectures are free to attend, but registration is mandatory**.

1st Edition of AGERP (2020)

- **Lecture 1: Mining Geotechnology**

  Learnings from the Brumadinho tailings dam failure, Professor David Williams

  Design and construction of the Hamata tailings dam, Hidden valley mine, Papua New Guinea, Mr. Mark Rynhoud

- **Lecture 2: Geophysics for Geotechnical Engineers**

  Geophysical properties of soils, Professor J. Carlos Santamarina

  Airborne geoscanning: combining artificial intelligence and airborne geophysics for more efficient site investigation, Dr. Andreas A. Pfaffhuber and Mr. Craig W. Christensen

- **Lecture 3: Advanced Numerical Methods and Modelling in Geotechnical Engineering**

  A particle-scale perspective on Dam engineering, Professor Catherine O'Sullivan

  Numerical modelling for slope stability analysis, Mr. David Wines

- **Lecture 4: Design of Pile foundations**

  The performance-based design of bored piles (drilled shafts) in clay, Emeritus Professor Malcolm Bolton

  Pile design in practice, Dr. Chris Haberfield

  Discussions and Closure: Discussion by Stephen Buttling, Closure by Malcolm Bolton

- **Lecture 5: Geohazards**

  Rainfall-induced slope processes and failures, Professor Sarah Springman

  What do we learn from seismic geotechnical failures? Dr. Barnali Ghosh

- **Lecture 6: Mechanics of Unsaturated Soils**

  An applied science for unsaturated soil mechanics, Professor Emeritus Delwyn G. Fredlund

  Numerical modeling of unsaturated soils problems, Dr. Murray Fredlund

- **Lecture 7: Biogeotechnics**

  Emerging opportunities in biogeotechnics, Professor Jason T. DeJong

  The essentials for successful biogeotechnical practice, Dr. Dimitrios Terzis

- **Lecture 8: Sensors and NDT Techniques in Geotechnical Engineering**

  Geotechnical infrastructure sensing, Professor Kenichi Soga

  Rapid non-destructive assessment of transport infrastructure, Dr. Wayne Muller

- **Lecture 9: Energy Geotechnics**

  Coupled multiphysics analysis of geo-energy problems, Professor Marcelo Sanchez

  The thermal behaviour of foundation piles used for heat exchange and storage, Dr. Fleur Loveridge

- **Lecture 10: Improvement of Soft Soils with special reference to Transport Infrastructure**

  Soft soils stabilisation through improved drainage and consolidation, Professor Buddhima Indraratna

  Semi-rigid and consolidation ground improvement techniques for embankment on soft clay-Lessons learnt from projects, Dr. AHM Kamruzzaman (Zaman)

- **Panel Discussion 1: Career Prospects in Geotechnical Engineering: Academia and Industry**

2nd Edition of AGERP (2021)

Lecture 1: Mechanically Stabilised Earth (MSE) Walls

Lessons learned from laboratory and field measurements of MSE wall performance, Professor Emeritus Richard J. Bathurst

Good practice, lessons learned & unusual fills in MSE design & construction, Ms. Chaido (Yuli) Doulala-Rigby

- **Lecture 2: AI and Big Data in Geotechnics**

  The Geotechnical Response to Big Data: Reactive or Proactive…. You Can Choose, Dr. Robert C. Bachus

  Scope and challenges in applications of AI techniques to Geotechnical Engineering, Prof. Sarat K. Das

  AI, Data & Geotechnics: The Exciting Future of Human-Machine Synergy and the Digital Transformation of the Geoprofession, Dr. Nick Machairas

- **Lecture 3: Geotechnics of Tailings Dams**

The shear strength of liquefied soils: updates and new developments, Prof. Scott Michael Olson

Improving governance will not be sufficient to avoid dam failures, Mr. Michael Jefferies

- **Lecture 4: In-situ Testing in Geotechnical Engineering**

  Advances in CPT applications, Professor Emeritus Peter K. Robertson

  The Flat Dilatometer (DMT) and Seismic Dilatometer (SDMT) for in-situ testing, Eng. Diego Marchetti

- **Lecture 5: Soil Erosion**

  Soil erosion and design applications, Professor Jean-Louis Briaud

  Erosion control techniques for drainage channels: From traditional methods to latest sustainable techniques, Mr. Amir Shahkolahi

CONTACT US:

Organising Committee
Advancements in Geotechnical Engineering: From Research to Practice
E: hello.agerp@gmail.com

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

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

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

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

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

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

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

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

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

37th General Assembly of the European Seismological Commission, Session: Advances in engineering seismology stemming from practice.

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

ITA Tunnelling Week, 20 to 24 September 2021, https://ita-aites.6connex.eu/event/ITAVirtualEvents/login

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

14th Basements and Underground Structures Conference / 10th biennial Instrumentation and Monitoring Conference, 6 October 2021, London, United Kingdom, https://basements.geplus.co.uk, https://monitoring.geplus.co.uk

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

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

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

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

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

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

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

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

5TH World Landslide Forum Implementation and Monitoring the USDR-ICL Sendai Partnerships 2015-2025, 2-6 November 2021, Kyoto, Japan, http://wlf5.iplhq.org

Tackling Modern Geotechnical Complexity with Physical Modelling

18th & 19th November 2021, Singapore

www.asiafuge-sg.com

Welcome to the 3rd Asian Conference on Physical Modelling in Geotechnics (Asiafuge), jointly organised by the National University of Singapore (NUS) and the Geotechnical Society of Singapore (GeoSS). Following the success of the 1st and 2nd series of the conference in India and Japan, we hope to continue this tradition of sharing state-of-art physical modelling technologies, methodologies as well as impactful outcomes from large scale geotechnical engineering experiments.

The theme of this conference is Tackling Modern Geotechnical Complexity with Physical Modelling, which embraces the spirit of enhancing and solving geotechnical challenges in infrastructure design, construction and resilience. The highlights include sharing and celebrating advances in: 1) equipment development, 2) advanced sensors and testing, 3) novel applications, physical vs numerical comparisons, 4) collaborative research projects, as well as 5) education and outreach in physical modelling in geotechnical engineering. Young researchers session and awards has been planned to encourage our next generation of bright researchers to take over the baton of gurus in several aspects of geotechnical engineering.

Despite the midst of the COVID-19 pandemic, participants would continue to be able to enjoy and participate in the conference via online while still keeping the personal touch through virtual networking sessions and technical laboratory tours by leading institutions.

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

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

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

16th ICGE 2022 – 16th International Conference on Geotehnical Engineering, Lahore, Pakistan, 23-24 February, 2022, https://16icge.uet.edu.pk/

15 - 17 March 2022, Kuala Lumpur, Malaysia
www.hydropower-dams.com/asia-2022

16th International Benchmark Workshop on Numerical Analysis of Dams, 6–8 April 2022, Ljubljana, Slovenia, https://icold-bw2022.fgg.uni-lj.si

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

2022 GEOASIA7 - 7th Asian Regional Conference on International Geosynthetics Society, April 11 - 15, 2022, Taipei, Taiwan, www.geoasia7.org

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

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

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

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

2022 ICOLD 27th Congress - 90th Annual Meeting 27 May - 3 June 2022, Marseille, France, https://cigb-icold2022.fr/en

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

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

3rd International Symposium on Geotechnical Engineering for the Preservation of Monuments and Historic Sites 22-24 June 2022, Napoli, Italy, https://tc301-napoli.org

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

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

Contact Information

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

5.ICNDSMGE – ZM 2020

5th International Conference on New Developments in Soil Mechanics and Geotechnical Engineering
June 30 to July 2, 2022, Nicosia, Cyprus
https://zm2020.neu.edu.tr

The conference is organised jointly by the Turkish Society of Soil Mechanics and Geotechnical Engineering and Near East University with the aim of bringing scientists, engineers, practitioners, and researchers together, to exchange knowledge and discuss the new developments in the field of soil mechanics and geotechnical engineering. The four previous conferences were participated by eminent ISSMGE members.

Themes and Topics

1. Laboratory testing and modelling
2. Geotechnical properties and improvement of soils
3. Analysis and evaluation of foundations
4. Earthquake geotechnical engineering and natural hazards
5. Environment preservation, water, and energy
6. Special and specific Issues
7. New methods in geotechnical engineering

Contact

Cavit Atalar
ZM2020
Organising Committee Chair
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UNSAT2022
8th International Conference on Unsaturated Soils
June or September 2022, Milos island, Greece

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

16th International Conference of the International Association for Computer Methods and Advances in Geomechanics – IACMAG
01-08-2022 – 02-09-2022, Torino, Italy

Organiser: Politecnico di Torino
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ISFOG 2020 4th International Symposium on Frontiers in Offshore Geotechnics, 28 – 31 August 2022, Austin, United States, www.isfog2020.org

11th International Symposium on Field Monitoring In Geomechanics
04-08 September 2022, London, United Kingdom

Organizer: TC220

Contact person: Dr Andrew Ridley; Email: andrew.ridley@geo-observations.com

The 17th Danube - European Conference on Geotechnical Engineering
5-7 September, 2022, Bucharest, Romania
https://sites.google.com/view/17decgero/home

Eurock 2022

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

You are invited to reunite with your colleagues on solid bedrock at the EUROCK 2022 - *Rock and Fracture Mechanics in Rock Engineering and Mining* in Espoo, Helsinki-region, Finland, 12 to 15 September 2022. The conference themes include but are not limited to latest advances in rock mechanics, interesting mining and rock engineering cases, and engineering education. The call for papers is now open.

The conference will feature two main tracks: the scientific track and the industrial track. The presentations will be arranged in general and parallel sessions over two days. There will be short courses and workshops on the day preceding the conference and excursions to sites of interest on the day following the conference.

Should the COVID-19 situation allow, the conference will be held in the Dipoli conference center in Espoo near the Aalto University campus in the Helsinki region. The touristic city of Helsinki will be at your disposal with its underground and above ground marvels. Virtual participation with networking possibilities will be offered in parallel.

Themes

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

Contact Person: Lauri Uotinen
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IAEG XIV Congress 2022

Chengdu, China September 14-20, 2022
https://iaeg2022.org

As a quadrennial global academic event initiated by the International Association for Engineering Geology and the Environment (IAEG), the IAEG Congress has been successfully held for 13 sessions, which aims to propagate the latest research results in the field of engineering geology and the environment, facilitate international academic exchanges and interdisciplinary integration, and promote the disciplinary construction of engineering geology and the environment. To further strengthen theoretical innovation, technological breakthrough and international cooperation in the field of engineering geology and the environment.

The XIV Congress of the International Association for Engineering Geology and the Environment will be held in **Chengdu Century City New International Convention and Exhibition Center**, Chengdu, China from **September 14 to 20, 2022**. Based on the theme of "**Engineering Geology for a Habitable Earth**", the congress is expected to enhance the disciplinary and research development of international engineering geology and the environment, and contribute to the advancement of major projects, ecological progress, and habitable earth with research and discussion in the engineering geology and global climate change, geological hazard assessment and prevention, geotechnical properties of rock and soil mass, engineering geology and the environmental issues concerning marine, transportation, urban and ecological environment protection in major projects, engineering geology and resilience engineering construction, intelligent engineering geology, and new theories, methods, and techniques in engineering geology, etc.

We warmly welcome the worldwide engineering geological community to come to Chengdu to participate in this academic event.

General scientific themes

- Climate Change Mitigation and Adaption
- Engineering Geology and Sustainable Development
- Mechanism, Monitoring and Early Warning, Prevention and Assessment of Geological Disasters
- Environmental Engineering Geology and Ecosystem Protection
- Geotechnical Properties of Rock and Soil Mass
- Traffic Engineering Geology and Sichuan-Tibet Railway Construction
- Energy Engineering Geology and Deep Earth Resource Exploitation
- Urban Engineering Geology and Underground Space Utilization
- Marine Engineering Geology and Coastal Development
- Polar, Planetary Engineering Geology and Disasters
- Artificial Intelligence, Big Data and Engineering Geology
- New Theory and Technology of Engineering Geology
- Preservation of Cultural Heritage and Engineering Geology
- Education and Disciplinary Development of Engineering Geology

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☙ ❧

28th European Young Geotechnical Engineers Conference and Geogames, 15 – 17 – 19 September 2022, Moscow, Russia, https://www.eygec28.com/?

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6th Australasian Ground Control in Mining Conference – AusRock 2022
17 – 19 September 2022, Melbourne, Australia

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

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10th International Conference on Physical Modelling in Geotechnics (ICPMG 2022), September 19 to 23, 2022, KAIST, Daejeon, Korea, https://icpmg2022.org

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

IX Latin American Rock Mechanics Symposium - Rock Testing and Site Characterization, an ISRM International Symposium, 16-19 October 2022, Asuncion, Paraguay, http://larms2022.com

AUSROCK Conference 2022, 6th Australasian Ground Control in Mining Conference –an ISRM Regional Symposium, 29 November–1 December 2022, Melbourne, Australia, www.ausimm.com/conferences-and-events/ausrock/

4th African Regional Conference on Geosynthetics – Geosynthetics in Sustainable Infrastructures and Mega Projects February 2023, Cairo, Egypt, www.geoafrica2023.org

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

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17th Asian Regional Geotechnical Engineering Conference
14-18 August 2023, Nur-Sultan, Kazakhstan

Organiser: Kazakhstan Geotechnical Society;
Contact person: Ms. Bibigul Abdrakhmanova;
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Phone: +7-7172- 34479;
Fax: +7-7172-353740;
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XII ICG - 12th International Conference on Geosynthetics, September 17 – 21, 2023, Rome, Italy, www.12icg-roma.org

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15th ISRM
International Congress in Rock Mechanics
9÷14 October 2023, Salzburg, Austria

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

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XVIII European Conference on Soil Mechanics and Geotechnical Engineering
25-30 August 2024, Lisbon, Portugal

Organiser: SPG
Contact person: SPG
Address: Av. BRASIL, 101
Email: spg@lnec.pt
Website: http://www.spgeotecnia.pt

ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

First scientific findings on Myanmar's mine landslide disaster in 2020

Rescuers carry a victim after the disaster in the jade mine.

For the first time after more than a year from the deadly jade mine landslide that occurred in Myanmar, scientists reveal data from a systematic investigation of the incident suggesting that poor planning and human errors led to the collapse.

In the morning of July 2, 2020, a rainfall-induced landslide struck an open-pit jade mine located in northern Myanmar. The ground failure swept through the site carrying debris and water that had filled the mine due to prolonged precipitation turning it into a "lake", killing at least 172 jade miners. An investigation conducted after the incident suggests that rainfall water has infiltrated the ground through cracks in the rock formations and led to pore-water pressure build-up that eventually destabilized the landslide mass sending a large volume of quarry material downslope. The devastating landslide and the generated wave of debris and water were caught on camera (click the video in the Media section below to watch the footage).

The government of Myanmar had ordered the closure of mining facilities the previous day due to the high risk of landsliding, however, illegal miners had occupied the place despite the warnings. Unfortunately, illegal jade mining in Myanmar is very common with people trying to assess mines in hazardous periods and with little equipment.

The new study, published in ISPRS Journal of Photogrammetry and Remote Sensing, utilized satellite and remote-sensing data to assess the conditions under which the landslide occurred. The team's purpose was: 1) to shed light on the circumstances that controlled the ground failure, and 2) document the failure and provide significant data and insights towards avoiding similar disasters in the future. Their findings suggest that, despite common assumptions that mainly put the blame on the heavy precipitation for the landslide, there were subsequent parameters (poor design and mismanagement) that also contributed to the event.

In particular, using the satellite imagery data, the team found that the mine walls were steeper than they should be taking into consideration the weak nature of the mine's rock material. This practically means that the slopes' factor of safety was already low before the heavy rainfalls strike. In fact, images showed that periodic landslides occurred in the mine between 2013 and 2020. Creating steeper slopes allows jade to be extracted more quickly but obviously compromises the safety of the mine.

Moreover, the study mentions that there was a fatal error associated with the storage of mine waste. Mine waste was deposited very close to the mine and due to its increased permeability, it absorbed a large amount of rainwater that eroded the walls of the open pit and potentially contributed to its failure. A mining geology consultant in Myanmar stated that, indeed, poor site conditions and steep slope formations could have played an important role in the incident, emphasizing that the mine design has not been conducted properly.

The study proposes more conservative slope designs for the open-pit jade mines in Myanmar: "Beyond the scope of a case study, we expect the technical developments and research findings to facilitate better site planning and landslide mitigation for on-going and future open-pit mines," the team concludes.

The authors also indicate that their analysis is conducted purely from a scientific point of view and does not comprise a criminal investigation.

Sources: Nature, Lin et al. (2021)

https://www.youtube.com/watch?v=cliO9pDuYXI

(Geoengineer.org, Jun, 29, 2021, https://www.geoengineer.org/news/first-scientific-evidence-of-myanmar-mine-landslide-disaster-in-2020?utm_source=twitter&utm_medium=social&utm_campaign=page_post)

Deadly Myanmar mine disaster caused by poor planning, say data sleuths

First scientific study of Myanmar's worst mining accident reveals that human error contributed to the 2020 disaster that killed at least 172 people.

A detailed analysis of satellite and remote-sensing data has uncovered poor conditions at the Wai Khar jade mine in northern Myanmar, where a landslide last July killed more than 170 people.

The international team of authors behind the study — the first to rigorously document a mining accident in Myanmar — says the results suggest that mismanagement and poor design contributed to the tragedy, not simply monsoon rains, as was initially assumed.

As well as shedding light on the causes of the disaster, which have not yet been fully resolved, the authors hope the findings will aid documentation of mine collapses and improve site planning — both in Myanmar and in other countries that see frequent mining accidents.

Hundreds of people were buried by a landslide when the wall of the Wai Khar open mine collapsed on 2 July 2020.

Mining of jade, largely for jewellery and carvings destined for China, has exploded in Myanmar in recent years. About 400,000 miners scavenge jade from the slopes of open-pit mines, often with little safety equipment. They feed an industry that supplies 90% of the world's jade and earned an estimated US$8 billion in 2011 — 20% of the southeast Asian state's export revenue.

Hundreds of deaths

The jade industry in Myanmar is poorly regulated and mine collapses are common, causing many hundreds of deaths since 2004, according to the study authors. But a lack of transparency from the Myanmar authorities — together with political and ethnic conflict in northern Kachin state, where jade mining is centred — means field surveys of mine sites are "nearly impossible", the authors argue.

In what is thought to have been Myanmar's worst mining disaster, in June last year rain began to saturate the ground at the northern section of the Wai Khar open-pit jade mine in the region of Hpakant. Eventually, on 2 July, a huge volume of quarry slope materials "collapsed into a flooded open pit, burying and killing at least 172 jade miners", write the authors.

Although mining companies in Hpakant had been ordered by the authorities to suspend operations from 1 July for three months for the monsoon season, impoverished freelance scavengers were still hunting for unpicked jade exposed by rain. Heavy rainfall was initially assumed to be the trigger for the collapse.

Myanmar's National Human Rights Commission blamed the landslide on the lack of due diligence and risk assessment from mining companies — at least 12 of which owned licences covering specific parts of the Wai Khar mine at the time of the accident. But non-governmental organizations say that a lack of regulatory oversight from the government in the mining industry is also a major problem endangering the lives of miners in Myanmar.

A spokesperson for Myanmar Gems Enterprise — the Myanmar government-owned regulator and issuer of mining licences — told *Nature* that mining operations at the Wai Khar open-pit mine ended on 29 June, before the accident, and that a government investigation concluded rainfall had infiltrated the ground through fractures in the rock, leading to the landslide. They added that the research findings will be valuable for assisting in future governance of the mining sector.

Myanmar's poorly regulated mines provide up to 90% of the world's jade.

The mining companies either could not be reached for comment on the study, or did not respond to *Nature*'s queries on the causes of the disaster.

Given the lack of access to mine sites in Myanmar, a team of researchers from Taiwan, Singapore, Brazil and Thailand used data from remote sensing and satellites to investigate the collapse. These are often used to monitor mine sites in nations that have strict mining regulations. "There are a lot of things we can do from space," says study co-author Wang Yu, a geologist at National Taiwan University in Taipei.

Aggressive mining cycles

To look for deformation in the landscape around the Wai Khar mine over time, Wang and his team combined online video footage of the accident from the ground with aerial and satellite data, as well as historical data from a NASA space-shuttle mission in 2000.

The authors found two factors that they think triggered the wall collapse, in addition to rainfall. Firstly, the walls of the mine were dangerously steep given the weak nature of the rock surrounding the pit. Google Earth images captured at intervals between 2013 and 2020 indicated periodic landslides had occurred in the pit, even where special steps had been dug out of the wall to prevent collapse, Wang says.

"The mining site is under aggressive mining cycles that are exacerbated by frequent, uncontrolled landslides," he and his co-authors write. This process allows jade to be extracted more quickly, but creates dangerous conditions.

"The argument that the slope was too steep is very likely to be correct," says Dave Petley, a geographer who studies landslides at the University of Sheffield, UK. He says he can't be sure the landslide was associated with mining practices, but that operations should be designed to prevent deformation. "The authors show that the mine walls were actively deforming before failure," he adds.

Poor mine design

Secondly, the study authors say that piles of mine waste acted like a sponge for rainfall or groundwater, and probably gradually leaked water that eroded the walls of the pit, aiding its collapse. The waste piles, detected in digital elevation data from NASA's space shuttle in 2000 and Japan's Advanced Land Observing Satellite from 2006–11, shouldn't have been so close to the mine, they say.

In an e-mail to *Nature*, the authors said that "there are issues of mismanagement and bad design in the pit", but stop short of blaming anyone for the collapse. "Our analysis is only from the scientific viewpoint. It should be considered as an autopsy report, not a criminal complaint," they said. "A thorough investigation will be needed in order to determine the correct share of responsibility among different parties."

Kyi Htun, an independent mining geology consultant in Myanmar's capital, Yangon, says that after reading the study, he thinks that poor site management — such as not monitoring how the slope changed over time and not disposing of waste properly — probably played a part in the accident. "No one has done mine design properly" at the Wai Khar mine, he says.

Assisting other nations

San Htoi, a spokesperson for advocacy group Kachin Women's Association Thailand, who visited the mine after the landslide, also says the findings are consistent with her observations: "The slope is too steep. It's so dangerous."

The authors of the study say they hope that the team's work will encourage other scientists to perform similar analyses in nations where mining is poorly regulated. Between 2004 and 2016, mine accidents led to deaths in 32 countries, according to one report[2].

As for the latest study, "It is a very comprehensive analysis of the mining accident," says Birendra Bajracharya, coordinator of SERVIR-Hindu Kush Himalaya in Kathmandu, an international initiative that uses geospatial technologies to inform responses to environmental challenges. "The methodology will be useful to other researchers," he adds.

Study co-author Yunung Nina Lin, a geologist at Academia Sinica in Taipei, says she hopes "the families of those who died can have a chance to learn about what had been happening on the mining site over the years", and that "those in power can take the messages from this research and transform them into real actions".

Nature **595**, 160-161 (2021)

doi: https://doi.org/10.1038/d41586-021-01740-2

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2. "Global fatal landslide occurrence from 2004 to 2016", Froude, M. J. & Petley, D. N. *Nat. Hazards Earth Syst. Sci.* **18**, 2161–2181 (2018). https://nhess.copernicus.org/articles/18/2161/2018/

(Andrew Silver / nature / NEWS, 29 June 2021, https://www.nature.com/articles/d41586-021-01740-2)

Slope simulator to further understanding of earthwork failures

Geotechnical engineers will acquire a greater understanding of catastrophic earthwork failures following the creation of a large-scale National Engineered Slope Simulator at Loughborough University.

Worldwide, landslides caused by earthquakes and heavy rainfall kill thousands of people annually. They also damage infrastructure and disrupt access to lifelines such as water supplies and transport links.

Despite the devasting consequences of earthwork failures there is limited understanding of why and when they occur. According to Loughborough University, there is currently no capability anywhere in the world to undertake simulations that would provide this information.

Now, the University has received a £500,000 grant from the Wolfson Foundation to create a simulator aimed at transforming national and international research capacity in this field.

"This is one of the most intriguing and important grants awarded this funding round," said Paul Ramsbottom, chief executive of the Wolfson Foundation. "It is based around brilliant science and will be one of the only facilities of its kind – not just in the UK but beyond."

Large-scale slopes will be constructed on a tilting table and subjected to cycles of controlled wetting and drying to simulate seasonal weather conditions. The table will be tilted and held at specified angles during this process, creating slope deterioration. Continuous monitoring, followed by rotating the slope to failure, will provide unique information on the impact of different weather patterns and extremes.

The tilting table will also provide an opportunity to investigate the performance of slope remediation interventions to an extent that has not been possible before, which will allow optimisation of slope repair and design.

The simulator is expected to enable engineers to design, deliver and maintain affordable and safe infrastructure that is resilient to the increasing environmental risks.

Professor Neil Dixon and Dr Alister Smith from Loughborough's School of Architecture, Building and Civil Engineering will lead the simulator project and the associated research programme, supported by a team of colleagues. They previously created the world's first commercial acoustic emission slope monitoring system and have conducted extensive research into slope failures.

In a statement, Professor Dixon said: "This exceptional facility will transform research capability in the geotechnical engineering sector. It will enable us to work with our academic and stakeholder partners across the UK to investigate and understand the causes of earthwork slope failures, optimise remediation strategies and inform the design of new infrastructure."

(THE ENGINEER, 30th July 2021, https://www.theengineer.co.uk/slope-simulator-earthwork-failures)

New piling solution will ensure both stability and energy from the ground

In partnership with Malvik municipality, the Norwegian Geotechnical Institute (NGI) will increase the use of geothermal heating in areas with thick deposits. For the buildings of the future the technology may increase the use of local thermal energy, reduce CO2 emissions, reduce pressure on the electricity grid and lead to cheaper electricity bills.

In Norway geothermal heating is most common as geothermal wells in bedrock. Such geothermal wells exploit heat from the bedrock and groundwater using a heat pump system. The short distance to the bedrock in many parts of the country make it easy to extract such heating or cooling.

The challenge is that more than 25 per cent of built-up areas in Norway have 30 metres or more of deposits above the bedrock. Such a great distance to the bedrock entails high costs when establishing geothermal heating systems with geothermal wells in bedrock. The distance can also pose challenges for operation of the facility.

"We recognise that there is a need for research on stable and reliable energy sources in urban areas. In parts of Trondheim and Oslo there are areas with a lot of deposits, such as clay and silt, that can make it difficult and costly to reach the bedrock to extract the energy in the normal manner. With new technology, we are going to change this," says project manager Sondre Gjengedal with NGI.

"Energy piles" a part of the structure of new buildings

In the project 'Sustainable energy from deposits (SEFD),' Malvik municipality will test and adapt a new solution for storage and extraction of energy using pile constructions in deposits. The solution is called 'energy piles.'

"In SEFD we will test how ordinary pile constructions can be designed for such purposes. The tests will be carried out as a pilot project at the Saksvik treatment plant in Malvik," Gjengedal says.

The project is funded by the Trøndelag Regional Research Fund (RFF) and is a partnership between Malvik municipality and the Saksvik treatment plant, and the project partners NGI, Fundamentering AS, Noranergy AS and Winns AS.

"In time, the goal is to implement energy piles as a part of the foundation solution for new builds where pile foundations are required due to thick deposits. By integrating energy solutions in the piles, we may be able to drastically reduce the installation costs for energy systems, and that would be yet another step in the right direction towards a smart and sustainable building," says project supervisor Tom André Havnes with Malvik municipality.

Challenging Nordic climate

Energy piles in deposits have to an increasing extent been used in southern Europe in the last decade. The most common method of implementing this is to integrate a loop of collector pipes in concrete piles.

"Unfortunately, our ever-changing Norwegian climate poses certain challenges in terms of the possible energy utilisation for such energy piles in this country. It's important that the system works optimally when we combine the piles with the foundation solutions," says Wilhelm Huus-Hansen with Noranergy AS.

The tests being carried out in this project will also entail that the energy piles will be adapted to the Nordic climate and Norwegian building practices.

"We hope and believe that a new and adapted design will increase the possibility for energy utilisation, energy storage and efficiency. At the same time we must ensure that the energy piles ensure stable foundations," Gjengedal says.

Increased growth of sustainable and energy efficient buildings

For Trøndelag, increased use of geothermal heating will be a local initiative for development towards a more sustainable society. At the same time, this will be a step in the right direction towards contributing to achieving the UN and EU goals for sustainable and energy-efficient buildings.

"Malvik municipality has several projects in the pipeline that may be suitable for energy piles, so we are hoping for good results," Havnes says.

To develop expertise with regard to the optimal design and use of energy piles, pilot projects are needed, such as the SEFD project.

"The goal is that the construction industry can use energy piles in areas with thick deposits, both domestically and internationally. This will lead to more sustainable cities and local communities," Gjengedal concludes.

The Norwegian Geotechnical Institute (NGI) is a leading international centre for research and consulting within the geosciences. NGI develops optimum solutions for society, and offers expertise on the behaviour of soil, rock and snow and their interaction with the natural and built environment. NGI works within the markets Offshore energy; Building, construction and transportation; Natural hazards, and Environmental Engineering. NGI is a private foundation with office and laboratory in Oslo, branch office in Trondheim, and daughter companies in Houston, Texas, USA, and Perth, Western Australia. NGI was established in 1953.

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(NGI News, Aug. 3, 2021, https://www.ngi.no/eng/News/NGI-News/New-piling-solution-will-ensure-both-stability-and-energy-from-the-ground)

☙ ❧

2020 Edenville and Sanford Dam Failures Panel

The Geo-Institute Embankments, Dams, and Slopes Committee presented on the Edenville and Sanford dam failures on September 18, 2020 as part of the ASCE Virtual Technical Conference.

https://www.youtube.com/watch?v=3DUKECw7suA

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A rockfall video from the Couloir du Gypaète in France

With thanks to those who spotted this on Youtube, a very surprising rockfall video was posted online last week by Rémi Bourdelle, who was flying above the Couloir du Gypaète in France when a rockfall developed. The video provides an utterly unique perspective on rockfall processes. Take a look:

https://www.youtube.com/watch?v=jsXldaiIC5o

My first reaction to this is of course wow! The video shows boulders bouncing down the gulley and then through the trees below. As noted previously the force of these rocks is extraordinary (https://blogs.agu.org/landslideblog/2021/07/26/batseri-1).

But the most surprising element of this video is the trajectory of the rock seen at the start of the video. Fortunately, this boulder (which appears to have been fragmenting) left a trail of dust that marks its path through the air:

The trajectory of the boulder at Couloir du Gypaète in France.

This is the sort of trajectory that is normally associated with fly rock from blasting rather than a rockfall. It is quite extraordinary; I have not seen this previously (have any readers?).

Presumably, the boulder struck an inclined surface, whilst travelling at a very high velocity, causing a ricochet that created this ballistic trajectory.

The other obviously possibility would be ejection during fracturing, but this seems less likely to me.

(Dave Petley / THE LANDSLIDE BLOG, 4 August 2021, https://blogs.agu.org/landslideblog/2021/08/04/couloir-du-gypaete-1)

☙ ❧

Nalda: a valley-blocking landslide in Himachal Pradesh, India

This morning (Friday 13 August 2021) a major landslide occurred near to the village of Nalda, in Lahaul and Spiti district in Himachal Pradesh, northern India, blocking the Chenab River. The landslide event itself was captured in a video that has been posted to Youtube:

https://www.youtube.com/watch?v=sicEFDJ9-2I

The landslide has left a large barrier across the Chenab River close to Nalda. The image below, from Tribune India, provides an overview of the situation:

The valley blocking landslide close to the village of Nalda in Himachal Pradesh in northern India.

This is not likely to remain breached for long given the topography of the land and the form of the barrier – indeed some reports suggest that some flow has been re-established. But even a few hours of impounded water has the potential to generate a substantial local flood, so there is a substantial hazard for villages downstream.

Note the very clear planar structures in the landslide scar. The failure is clearly defined by two existing joints or faults, meeting with a c.90 degree angle. Note also the landslide scar immediately to the left of the landslide scar. That must also have been a substantial failure event.

This landslide comes on the back of a significant landslide in India on Wednesday, when a slope above a road in India collapsed, burying several vehicles including a bus. Recovery operations continue at the site, but at the time of writing 15 bodies have been recovered. There are fears that there may be substantially higher levels of loss. The Indian Express reports that Chief Minister Jai Ram Thakur has indicated that up to 60 people were feared trapped under the debris at the time of the accident. Rescue operations are being hampered by ongoing instability on the slope.

(Dave Petley / THE LANDSLIDE BLOG, 13 August 2021, https://blogs.agu.org/landslideblog/2021/08/13/nalda-1/)

☙ ❧

Investigation of potential landslide in Parton, England

Numerous people were evacuated to investigate the risk of a potential landslide in western England.

The landslip was detected in Parton, a village on the Cumbrian coast in the United Kingdom on July 28, 2021. In particular, authorities found cracks in a village's hill near which houses have been constructed. The nearest structure was detected at about 6 meters away from the cracks. A major crack was detected at the crown of the landslide and measured around 1 meter. Initial reports made mention that the landslip was caused by heavy rainfalls which followed a dry period.

Officials decided to evacuate the area in fear of potential slippage that could carry away the infrastructure. 14 residences were evacuated and a road was closed. The affected area could include a school and a children's playground. The Cumbria County Council initiated a series of in-situ investigations in which experts assessed the conditions of the potential ground instability. It was suggested that the residents could stay out of their houses for a long period and the road could be closed for up to 6 months.

The residents were accommodated in temporary shelters as engineers conducted fieldwork. Some people were allowed to return to their houses to collect necessary stuff. The council stated that the fieldwork is challenging since vegetation should be removed to assess the situation. Moreover, there was significant uncertainty about the volume of the potential landslide. "It's too early to say as to how much of the embankment could potentially come down, we're talking thousands of tons rather than hundreds of tons. It's a very complex piece of work that we're doing in resolving the issue, but also ascertaining land ownership," Karl Melville, Cumbria Highways senior manager, stated.

On August 4, 2021, it was announced that a klaxon warning system has been installed to alert people in case the properties need to be instantly evacuated. Hence, people were allowed to return to their residences. However, the assessment of the landslip is still a matter of investigation. Geotechnical engineers stated that the cracks may have appeared due to vegetation dying off as a result of dry weather and high temperatures. They also suggest that the noise that was initially attributed to slippage derived from another source. Further tests will be carried out to assess the stability of the region. It is still unclear how long the fieldwork will continue and when authorities will decide if any measures will be applied.

In any case, the Cumbria County Council is looking to relocate the school facility to a safer place nearby by the time the holidays end.

Footage from the landslip can be found in the video below https://www.youtube.com/watch?v=8mFWQOnFSPo.

The story unfolds here and in 4 articles from the *BBC:*

Sources: Article1, Article2, Article3, Article4

(Geoengineer.org, Jul, 28, 2021, https://www.geoengineer.org/news/investigation-of-potential-landslide-in-parton-england?utm_source=twitter&utm_medium=social&utm_campaign=page_post)

☙ ❧

Landslide in the Çayeli district Esendağ village

After the heavy rain in Rize, the 3-storey building drifted along with the soil and fell on its side in the landslide in the Çayeli district Esendağ village

(Civil Engineering Discoveries, Aug 15, 2021, https://twitter.com/CivilEngDis/status/1426817654296223747)

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Vehicles, passengers run away as landslide brings down trees, debris on Uttarakhand, India, highway

A new video has emerged from Uttarakhand, India, showing a landslide in Champawat area in which vehicles with passengers in them are seen trying to flee with debris rolling down the slope.

Yet another landslide in Uttarakhand has blocked the national highway connecting Tanakpur with Champawat. A video that has emerged from the landslide spot shows scores of vehicles with passengers in them standing on the road as a large portion of the hill comes crashing down.

https://www.indiatoday.in/india/story/uttarakhand-champawat-landslide-passengers-flee-video-1844510-2021-08-24

The Tanakpur-Champawat national highway was blocked following the landslide near Swala in Champawat of Uttarakhand on Monday, reported news agency ANI.

The video shows rocks, soil and tons of debris rolling down the slope and uprooting trees on the way as horrified commuters look on.

The cars and other vehicles then scramble on the highway to make a U-turn to get away from the landslide even as the road is choked by the vehicles.

District Magistrate Vineet Tomar said, “It would take at least two days to clear the debris. I have instructed officials concerned to divert the traffic to another route.”

A few weeks ago, a major landslide in Kinnaur of Himachal Pradesh led to at least 28 deaths with many still missing after debris and boulders rolled down the slope to bury a bus full of passengers, several vehicles and a truck commuting on the highway.

Rescue workers have so far managed to recover about 28 bodies while many are still missing.

The HRTC bus was found in a badly damaged condition on Thursday.

A truck, which had rolled down a riverside due to stones falling down a mountainside, was also found and the driver's body was recovered. Two more cars were found in fully damaged condition, but no one was found inside them.

(India Today, August 24, 2021, https://www.indiatoday.in/india/story/uttarakhand-champawat-landslide-passengers-flee-video-1844510-2021-08-24)

Pile Testing

Impressive pile vertical load test setup at the Burj Khalifa construction. The Burj Khalifa is on 192 bored piles of 1.5 m diameter and 43 meters length, to take the weight of the building.

(https://www.linkedin.com/feed/?midToken=AQHDsV0w0ilyeg&midSig=1GmC-0wVdTmFU1&trk=eml-jobs_jymbii_digest-header-47-home&trkEmail=eml-jobs_jymbii_digest-header-47-home-null-3z1n6p%7Ekshpelck%7Ev0-null-neptune%2Ffeed)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ & ΑΝΤΙΣΕΙΣΜΙΚΗ ΜΗΧΑΝΙΚΗ

Integrating macroseismic intensity distributions with a probabilistic approach: an application in Italy

Andrea Antonucci, Andrea Rovida, Vera D'Amico, and Dario Albarello[3]

Abstract

The geographic distribution of earthquake effects quantified in terms of macroseismic intensities, the so-called macroseismic field, provides basic information for several applications including source characterization of pre-instrumental earthquakes and risk analysis. Macroseismic fields of past earthquakes as inferred from historical documentation may present spatial gaps, due to the incompleteness of the available information. We present a probabilistic approach aimed at integrating incomplete intensity distributions by considering the Bayesian combination of estimates provided by intensity prediction equations (IPEs) and data documented at nearby localities, accounting for the relevant uncertainties and the discrete and ordinal nature of intensity values. The performance of the proposed methodology is tested at 28 Italian localities with long and rich seismic histories and for two well-known strong earthquakes (i.e., 1980 southern Italy and 2009 central Italy events). A possible application of the approach is also illustrated relative to a 16th-century earthquake in the northern Apennines.

How to cite.

Antonucci, A., Rovida, A., D'Amico, V., and Albarello, D.: Integrating macroseismic intensity distributions with a probabilistic approach: an application in Italy, Nat. Hazards Earth Syst. Sci., 21, 2299–2311, https://doi.org/10.5194/nhess-21-2299-2021, 2021.

1 Introduction

Characterizing earthquake effects on the anthropic environment is of paramount importance for estimating seismic risks and planning prevention policies. This characterization is performed by classifying earthquake effects according to macroseismic scales. Each macroseismic scale considers a set of scenarios, 12 in the most used scales in Europe (i.e., MCS – Sieberg, 1932; MSK – Medvedev et al., 1964; EMS-98 – Grünthal, 1998), ordered in terms of increasing severity of the effects. Through macroseismic scales, observed seismic effects concerning human behavior, damage to buildings and geomorphological phenomena at a site are compared with the scenarios proposed in the scale to assess an intensity value. An intensity value, referring to a specific earthquake and a specific place identified through its geographic coordinates, defines the intensity data point (IDP in the following). The spatial distribution of IDPs is considered for the characterization of the earthquake source (i.e., estimates of epicentral location and magnitude) in the absence of instrumental data (e.g., Bakun and Wentworth, 1997; Gasperini et al., 1999, 2010; Provost and Scotti, 2020). Collecting these parameters in homogeneous seismic catalogues (e.g., Fäh et al., 2011; Stucchi et al., 2013; Manchuel et al., 2018; Rovida et al., 2019, 2020) is a key element to providing a seismic characterization of a region, and this information represents a basic tool for seismic hazard estimates (e.g., Stucchi et al., 2011; Woessner et al., 2015; Meletti et al., 2021). In particular, in countries with rich macroseismic data (e.g., Italy and France) the histories of documented earthquake effects at a site can be consistently used for local seismic hazard assessment (e.g., Albarello and Mucciarelli, 2002; D'Amico and Albarello, 2008). Moreover, macroseismic intensity can be useful to check the outcomes of probabilistic seismic hazard assessments (Stirling and Petersen, 2006; Mucciarelli et al., 2008; Rey et al., 2018), especially in countries where the historical record is much longer than the instrumental one.

Retrieving seismological data from documentary information requires specific methodologies and expertise (e.g., Guidoboni and Stucchi, 1993) and presents several criticalities mainly due to the incompleteness of the documentation (e.g., Albarello et al., 2001; Swiss Seismological Service, 2002; Stucchi et al., 2004; Hough and Martin, 2021). The probability of retrieving such documentation depends on the period, size and location of the event and is hampered by the survival of sources and the capability of retrieving and analyzing them (e.g., Albini and Rovida, 2018; Albini, 2020a, b). This implies that intensity distributions of historical events may present important gaps, which depend also on the density and importance of the settlements affected by the earthquakes.

To fill these gaps, documented seismic effects may be integrated with "synthetic" intensities, which can be estimated in different ways. Until the second half of the 20th century, qualitative contouring procedures were used to draw isoseismal maps (e.g., Shebalin, 1974; Barbano et al., 1980; Postpischl et al., 1985; Ferrari and Postpischl, 1985; Patané and Imposa, 1985), in which hand-drawn isoseismals bounded areas enclosing sites with intensity overcoming any given threshold (Musson and Cecić, 2012). This form of regularizetion aims at reconstructing a general radiation pattern for historical earthquakes but is affected by biases induced by the conceptual background of the "tracer". To overcome this drawback, some authors (Ambraseys and Douglas, 2004; Rey et al., 2018) proposed geostatistical approaches (e.g., Olea, 1999) to identify areas affected by similar seismic effects. They applied the kriging spatial interpolation technique to compute the expected values of macroseismic intensity through a semivariogram that describes the correlation between neighboring IDPs. This kind of approach, however, disregards the inherent ordinal and discrete nature of intensity data, which requires specific formalizations to account for uncertainty affecting intensity estimates (see, e.g., Magri et al., 1994; Albarello and Mucciarelli, 2002).

An alternative approach to obtaining synthetic intensities makes use of intensity prediction equations (IPEs), which provide the possible intensity values at any site as a function of the epicentral distance and maximum or epicentral intensity or magnitude (e.g., Pasolini et al., 2008; Sørensen et al., 2009; Allen et al., 2012; Rotondi et al., 2016). The limitation of this approach is the hypothesis that the radiation pattern of seismic waves from the source is the only one responsible for the intensity at a site, disregarding lateral heterogeneities induced by the fracture process and geological and/or geomorphological features.

To account for these features, we present an alternative probabilistic approach, which improves the one proposed by Albarello et al. (2007) and D'Amico and Albarello (2008). The key element is a combination, through a Bayesian approach, of probabilistic estimates provided by an IPE constrained by observed intensities that are spatially close to the site of interest. The proposed procedure is described first; then it is tested on a set of localities and macroseismic fields included in the Italian Macroseismic Database DBMI15 (Locati et al., 2019).

(https://nhess.copernicus.org/articles/21/2299/2021/)

Understanding the nature of friction on earthquake faults by studying a volcanic eruption

Kilauea summit crater after the collapse in 2018.

A new study, recently published in the Proceedings of the National Academy of Sciences of the United States of America (PNAS), focuses on a volcanic flank collapse to understand how frictional resistance works on faults.

Fault friction is a critical parameter that is used to assess earthquake events. In general, friction is the resisting force that prevents the relative motion between solid surfaces such as the two sides of a fault. Before an earthquake event, static friction keeps the fault surface from moving but once displacement takes place, dynamic friction impacts how much the two sides will moving against each other. Hence, dynamic friction controls the magnitude and intensity of a seismic shock, the nature of shaking and the residual stresses on rocks. Unfortunately, the nature and the characteristics of dynamic friction have not been completely interpreted yet and thus, uncertainties in earthquake modeling emerge.

Researchers have not fully understood the role of friction in earthquakes mostly due to experimental challenges. The laboratory techniques involve tests in rock slabs that are far smaller than the actual ones. Hence, there is a scale effect that should possibly be taken into consideration. It is not certain that the experimental setup leads to biased results but validation is certainly necessary. "It's not something that we can entirely predict using only equations. We also need data from experiments," Paul Segall, the lead author of the study and a Professor of Geophysics at Stanford University, stated. The study assesses the slipping mechanism of the eastern flank of Kīlauea Volcano that occurred in April 2018.

The 2018 Kīlauea Eruption

In March 2018, researchers from the Hawaiian Volcano Observatory detected quick inflation rates at Puʻu ʻŌʻō, a cone in the eastern zone of the Kīlauea Volcano raising fears of a potential eruption. The high internal pressure led to lava drainage from the Puʻu ʻŌʻō's crater and to the collapse of its floor. Over the next days, new fissures emerged and impacted parts of the natural environment and local infrastructure. About 700 buildings were destroyed and many people were relocated. During the new 3 months, a stunning volume of lava was ejected from the volcano and the landscape was completely altered as the crater was displaced by more than 450 meters (due to its collapse). The event triggered numerous earthquakes with the majority being relatively small.

The crater collapsed in phases and in a non-progressive pattern. In particular, it would move by about 2.5 meters and then stop for 1.5 days (on average). This was observed as magma exited the chamber below the crater removing the support of the overlying formation. The crate's displacement was well-documented by an array of GPS instruments. The periodic phenomenon was repeated multiple times with each one triggering a seismic shock.

The fact that the eruptive vent was at a lower elevation than the collapsing crater was detrimental for the eruptive episode. The weight of the caldera created additional pressure into the magma chamber leading to the ejection of extra lava volume.

The authors of the study aimed at understanding how the collapse sequence of the crater evolved taking into consideration the role of friction.

Findings on the role of friction

The researchers utilized the GPS and tilt instrumentation data to model a piston collapse into a magma reservoir. A great finding is that their model confirms the results of small-scale laboratory tests. Hence, the derived slippage patterns in actual faults validate laboratory friction parameters at the kilometer scale. "These results support the use of laboratory friction laws and parameters for modeling earthquakes," the study mentions.

The new model found that the transition zone between static and dynamic friction does not occur instantly but involves a steady, complex process. The findings provide an upper limit of a parameter known as the slip-weakening distance. This refers to the distance before the frictional strength of a fault is significantly reduced and slippage becomes easier. Depending on the scale, it may range between micrometers to 20 centimeters. The model developed for the Puʻu ʻŌʻō crater suggests the slip-weakening distance is up to 10 millimeters, consistent with the predictions derived from lab tests. What this means is that it's "...okay taking those (lab) measurements from really small samples and applying them to big tectonic faults because they held true in the behavior we observed in Kīlauea's collapse."

The videos below include a flight above the Puʻu ʻŌʻō crater in early June 2018 and lava scenes from Kīlauea's "Fissure 8" captured on June 29, 2020.

Sources: Stanford, Segall and Anderson (2021), Caltech, NPS

(Geoengineer.org, Aug, 20, 2021, https://www.geoengineer.org/news/understanding-the-nature-of-friction-on-earthquake-faults-by-studying-a-volcanic-eruption)

Repeating caldera collapse events constrain fault friction at the kilometer scale

Paul Segall and Kyle Anderson

Significance

Earthquake physics require understanding how the frictional resistance on faults varies leading up to and during seismic slip. Laboratory rock friction experiments have led to widely used friction laws that depend on sliding rate and slip history. However, these experiments are restricted to samples vastly smaller than natural faults. Highly repeatable, and exceptionally well instrumented, caldera collapse events at Kīlauea volcano can be treated as kilometer-scale rock friction experiments and entirely validate laboratory experiments. Caldera collapse is caused by rapid draining of magma from a shallow crustal reservoir. Collapse transfers weight to the underlying magma reservoir, thereby sustaining the eruption. Our results permit more accurate understanding of conditions leading to caldera collapse and high-rate basaltic eruptions.

Abstract

Fault friction is central to understanding earthquakes, yet laboratory rock mechanics experiments are restricted to, at most, meter scale. Questions thus remain as to the applicability of measured frictional properties to faulting in situ. In particular, the slip-weakening distance *dc*

strongly influences precursory slip during earthquake nucleation, but scales with fault roughness and is challenging to extrapolate to nature. The 2018 eruption of Kīlauea volcano, Hawaii, caused 62 repeatable collapse events in which the summit caldera dropped several meters, accompanied by *MW* 4.7 to 5.4 very long period (VLP) earthquakes. Collapses were exceptionally well recorded by global positioning system (GPS) and tilt instruments and represent unique natural kilometer-scale friction experiments. We model a piston collapsing into a magma reservoir. Pressure at the piston base and shear stress on its margin, governed by rate and state friction, balance its weight. Downward motion of the piston compresses the underlying magma, driving flow to the eruption. Monte Carlo estimation of unknowns validates laboratory friction parameters at the kilometer scale, including the magnitude of steady-state velocity weakening. The absence of accelerating precollapse deformation constrains *dc* to be ≤10 mm, potentially much less. These results support the use of laboratory friction laws and parameters for modeling earthquakes. We identify initial conditions and material and magma-system parameters that lead to episodic caldera collapse, revealing that small differences in eruptive vent elevation can lead to major differences in eruption volume and duration. Most historical basaltic caldera collapses were, at least partly, episodic, implying that the conditions for stick–slip derived here are commonly met in nature.

PNAS July 27, 2021 118 (30) e2101469118;
https://doi.org/10.1073/pnas.2101469118
https://www.pnas.org/content/118/30/e2101469118

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

Greece's Santorini volcano erupts more often when sea level drops

Lower sea levels over the last 360,000 years are linked with more eruptions

Sea level seems to influence eruptions from the partially-submerged volcano of Santorini in Greece (pictured). Lower sea levels are historically linked to more eruptions.

When sea level drops far below the present-day level, the island volcano Santorini in Greece gets ready to rumble.

A comparison of the activity of the volcano, which is now partially collapsed, with sea levels over the last 360,000 years reveals that when the sea level dips more than 40 meters below the present-day level, it triggers a fit of eruptions. During times of higher sea level, the volcano is quiet, researchers report online August 2 in *Nature Geoscience*.

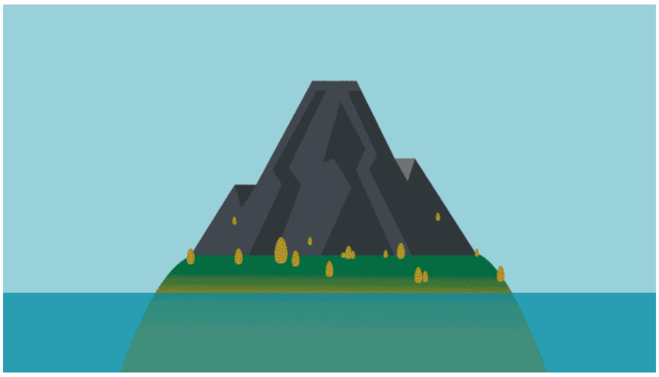
Other volcanoes around the globe are probably similarly influenced by sea levels, the researchers say. Most of the world's volcanic systems are in or near oceans.

"It's hard to see why a coastal or island volcano would not be affected by sea level," says Iain Stewart, a geoscientist at the Royal Scientific Society of Jordan in Amman, who was not involved in the work. Accounting for these effects could make volcano hazard forecasting more accurate.

Santorini consists of a ring of islands surrounding the central tip of a volcano poking out of the Aegean Sea. The entire volcano used to be above water, but a violent eruption around 1600 B.C. caused the volcano to cave in partially, forming a lagoon. That particular eruption is famous for potentially dooming the Minoan civilization and inspiring the legend of the lost city of Atlantis (*SN: 2/1/12*).

To investigate how sea level might influence the volcano, researchers created a computer simulation of Santorini's magma chamber, which sits about four kilometers beneath the surface of the volcano. In the simulation, when the sea level dropped at least 40 meters below the present-day level, the crust above the magma chamber splintered. "That gives an opportunity for the magma that's stored under the volcano to move up through these fractures and make its way to the surface," says study coauthor Christopher Satow, a physical geographer at Oxford Brookes University in England.

According to the simulation, it should take about 13,000 years for those cracks to reach the surface and awaken the volcano. After the water rises again, it should take about 11,000 years for the cracks to close and eruptions to stop.



When the sea drops at least 40 meters below the present-day level, the crust beneath the Santorini volcano (illustrated) starts to crack. As the sea level drops even further over thousands of years, those cracks spread to the surface, bringing up magma that feeds volcanic eruptions.Oxford Brookes University

It may seem counterintuitive that lowering the amount of water atop the magma chamber would cause the crust to splinter. Satow compares the scenario to wrapping your hands around an inflated balloon, where the rubber is Earth's crust and your hands' inward pressure is the weight of the ocean. As someone else pumps air into the balloon — like magma building up under Earth's crust — the pressure of your hands helps prevent the balloon from popping. "As soon as you start to release the pressure with your hands, [like] taking the sea level down, the balloon starts to expand," Satow says, and ultimately the balloon breaks.

Satow's team tested the predictions of the simulation by comparing the Santorini volcano's eruption history — preserved in the rock layers of the islands surrounding the central volcano tip — with evidence of past sea levels from marine sediments. All but three of the volcano's 211 well-dated eruptions in the last 360,000 years happened during periods of low sea level, as the simulation predicted. Such periods of low sea level occurred when more of Earth's water was locked up in glaciers during ice ages.

"It's really intriguing and interesting, and perhaps not surprising, given that other studies have shown that volcanoes are sensitive to changes in their stress state," says Emilie Hooft, a geophysicist at the University of Oregon in Eugene, who wasn't involved in the work. Volcanoes in Iceland, for instance, have shown an uptick in eruptions after overlying glaciers have melted, relieving the volcanic systems of the weight of the ice.

Volcanoes around the world are likely subject to the effects of sea level, Satow says, though how much probably varies. "Some will be very sensitive to sea level changes, and for others there will be almost no impact at all." These effects will depend on the depth of the magma chambers feeding into each volcano and the properties of the surrounding crust.

But if sea level controls the activity of any volcano in or near the ocean, at least to an extent, "you'd expect all these volcanoes to be in sync with one another," Satow says, "which would be incredible."

As for Santorini, given that the last time sea level was 40 meters below the present-day level was about 11,000 years ago — and sea level is continuing to rise due to climate change — Satow's team expects the volcano to enter a period of relative quiet right about now (*SN: 3/14/12*). But two major eruptions in the volcano's history did happen amid high sea levels, the researchers say, so future violent eruptions aren't completely off the table.

A version of this article appears in the August 28, 2021 issue of *Science News*.

Citations

C. Satow *et al*. Eruptive activity of the Santorini Volcano controlled by sea-level rise and fall. *Nature Geoscience*. Published online August 2, 2021. doi: 10.1038/s41561-021-00783-4.

(Maria Temming / Science News, August 2, 2021, https://www.sciencenews.org/article/greece-santorini-volcano-eruption-sea-level)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

Οι Βαβυλώνιοι είχαν βρει το Πυθαγόρειο θεώρημα 1.000 χρόνια πριν, λέει Αυστραλός καθηγητής

Η βαβυλωνιακή πλάκα με βάση την οποία διατυπώνει τις θεωρίες του Αυστραλός καθηγητής. Πηγή ΑΠΕ-ΜΠΕ / UNSW

Ένας Αυστραλός μαθηματικός ισχυρίζεται ότι ανακάλυψε τις ρίζες της εφαρμοσμένης γεωμετρίας σε μία πήλινη βαβυλωνιακή πλάκα ηλικίας περίπου 3.700 ετών.

Η πλάκα, που χρονολογείται μεταξύ του 1900 και 1600 π.Χ., είχε ανακαλυφθεί στο κεντρικό Ιράκ το 1894 και όλα αυτά τα χρόνια βρισκόταν στο Αρχαιολογικό Μουσείο της Κωνσταντινούπολης, χωρίς να έχει γίνει αντιληπτή η σημασία της για την ιστορία των μαθηματικών.

Η πλάκα με την ονομασία Si.427, η οποία δημιουργήθηκε από κάποιον Βαβυλώνιο «τοπογράφο», μελετήθηκε από τον δρα Ντάνιελ Μάνσφιλντ του Πανεπιστημίου της Νέας Νότιας Ουαλίας στο Σίδνεϊ, ο οποίος έκανε και τη σχετική δημοσίευση στο επιστημονικό περιοδικό «Foundations of Science».

Σύμφωνα με τον ίδιο, «πρόκειται για το μοναδικό γνωστό παράδειγμα κτηματολογικού "εγγράφου" από την αρχαία βαβυλωνιακή περίοδο του 1900-1600 π.Χ. και αφορά ένα σχέδιο που χρησιμοποιούσαν οι "τοπογράφοι" για να καθορίζουν τα χερσαία όρια. Στη συγκεκριμένη περίπτωση, περιέχει νομικές και γεωμετρικές λεπτομέρειες σχετικά με ένα κτήμα που χωρίστηκε μετά την πώληση ενός τμήματός του».

Θεωρείται σημαντικό ότι ο «τοπογράφος» χρησιμοποιεί τις λεγόμενες «Πυθαγόρειες τριάδες» για να δημιουργήσει ακριβείς ορθές γωνίες. «Η ανακάλυψη και η ανάλυση της πλάκας έχουν σημαντικές επιπτώσεις για την ιστορία των μαθηματικών. Για παράδειγμα, η πλάκα δημιουργήθηκε πάνω από **χίλια χρόνια προτού γεννηθεί ο Πυθαγόρας**», δήλωσε ο Μάνσφιλντ.

Το 2017, ο ίδιος Αυστραλός μαθηματικός είχε εικάσει ότι μία άλλη πλάκα της ίδιας περιόδου, γνωστή ως «Πλίμπτον 322», αποτελεί μοναδικό δείγμα τριγωνομετρικού πίνακα. Όπως ανέφερε, «είναι γενικά αποδεκτό ότι η τριγωνομετρία -ο κλάδος των μαθηματικών που ασχολείται με τη μελέτη των τριγώνων- αναπτύχθηκε από τους αρχαίους Έλληνες που μελετούσαν τον νυχτερινό ουρανό κατά τον 2ο αιώνα π.Χ. Όμως οι Βαβυλώνιοι είχαν αναπτύξει τη δική τους εναλλακτική "πρωτο-τριγωνομετρία" για να λύνουν προβλήματα σχετικά με μετρήσεις επί του εδάφους και όχι στον ουρανό»".

Η πλάκα Si.427 θεωρείται ότι υπήρξε πριν και από την «Πλίμπτον 322». Ήδη από το 2017 ο Μάνσφιλντ είχε υποθέσει ότι τέτοιες πλάκες χρησιμεύσαν για πρακτικούς σκοπούς, όπως η κατασκευή παλατιών, ναών και καναλιών ή ο καθορισμός ορίων κτημάτων.

«Με τη νέα πλάκα μπορούμε, πράγματι, να δούμε για πρώτη φορά γιατί (οι Βαβυλώνιοι) ενδιαφέρονταν για τη γεωμετρία: Ήθελαν να χαράζουν ακριβή όρια στο έδαφος. Ήταν μία περίοδος που η γη άρχιζε να γίνεται ιδιωτική και οι άνθρωποι άρχισαν να σκέφτονται με όρους "η γη μου και η γη σου". Ήθελαν, έτσι, να χαράζουν ξεκάθαρα όρια, προκειμένου να έχουν καλές σχέσεις με τους γείτονές τους. Ακριβώς αυτό αφορά και η εν λόγω πλάκα: Ένα χωράφι διαχωρίστηκε και νέα όρια χαράχτηκαν», σημείωσε ο Μάνσφιλντ.

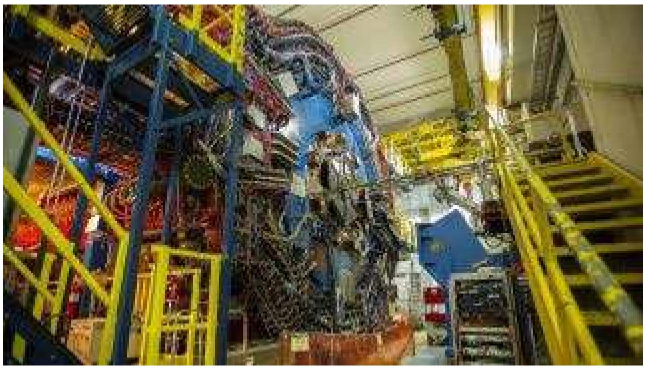
Άλλες πλάκες, που έχουν ήδη βρεθεί από εκείνη την περίοδο στη Βαβυλώνα, αποκαλύπτουν όντως ότι υπήρχαν διαφωνίες σχετικά με τα σύνορα των κτημάτων και για το ποιος ήταν π.χ. ο ιδιοκτήτης πολύτιμων δέντρων όπως οι φοίνικες, που βρίσκονταν κοντά στο όριο των γειτνιαζόντων κτημάτων. Σε τέτοιες περιπτώσεις, επιθεωρητές-τοπογράφοι καλούνταν να διευθετήσουν τη διαφωνία και η εφαρμοσμένη γεωμετρία ήταν ένα πολύ χρήσιμο εργαλείο.

Τέλος, η πλάκα Si.427 περιέχει κι ένα μυστήριο: Στο πίσω μέρος της φέρει εμφανώς τους αριθμούς 25:29, χωρίς να έχει κανείς ιδέα περί τίνος πρόκειται. «Είναι το απόλυτο αίνιγμα», δήλωσε ο Μάνσφιλντ.

(HELLAS JOURNAL, 05.08.2021, https://hellasjournal.com/2021/08/i-vavilonii-ichan-vri-to-pithagorio-theorima-1-000-chronia-prin-lei-afstralos-kathigitis/)

Famous Einstein equation used to create matter from light for first time

Two colliding light particles were used to create a matter-antimatter pair



The STAR detector at Brookhaven National Laboratory detected the matter-antimatter pairs created by the colliding light.

In a stunning demonstration of one of Einstein's most famous equations, physicists are claiming to have created matter from pure light for the very first time.

Albert Einstein's famous $E=mc^2$ equation says that if you smash two sufficiently energetic photons, or light particles, into each other, you should be able to create matter in the form of an electron and its antimatter opposite, a positron.

But this process, first described by American physicists Gregory Breit and John Wheeler in 1934, has long been one of the most difficult to observe in physics — mainly because the colliding photons would need to be highly energetic gamma rays, and scientists are not yet able to make gamma ray lasers. Alternative experiments have shown matter being produced from multiple photons, but never in the one to one way needed to most conclusively prove the effect.

But researchers from the Brookhaven National Laboratory in New York now believe they've found a workaround. Using the laboratory's Relativistic Heavy Ion Collider (RHIC), they have been able to produce measurements that closely match predictions for the strange transforming act.

"In their paper, Breit and Wheeler already realized this is almost impossible to do," Zhangbu Xu, a physicist at Brookhaven Lab, said in a statement. "Lasers didn't even exist yet! But Breit and Wheeler proposed an alternative: accelerating heavy ions. And their alternative is exactly what we are doing at RHIC."

Instead of accelerating the photons directly, the researchers sped up two ions — atomic nuclei stripped of their electrons and therefore positively charged — in a big loop, before sending them past each other in a near collision. As the ions are charged particles moving very close to the speed of light, they also carry an electromagnetic field with them, inside of which are a bunch of not-quite-real 'virtual' photons "traveling with [the ion] like a cloud," Xu explained.

Virtual particles are particles that only pop into existence very briefly as disturbances in the fields that exist between real particles. They don't have the same masses as their real counterparts (unlike their real counterparts that have no mass, virtual photons do have a mass). In this experiment, when the ions zipped past each other in a near miss, their two clouds of virtual photons were moving so fast they acted as if they were real. The real-acting virtual particles collided — producing a very-much-real electron-positron pair that the scientists detected.

To be a true observation of the Breit-Wheeler process, or as true as possible using virtual particles, the physicists had to make sure that their virtual photons were behaving like real ones. To check the virtual photons' behavior, the physicists detected and analyzed the angles between more than 6,000 electron-positron pairs produced by their experiment.

When two real particles collide, the secondary products should be produced at different angles than if they were made by two virtual particles. But in this experiment, the virtual particles' secondary products bounced off at the same angles as secondary products from real particles. So, the researchers could verify that the particles they were seeing were behaving as if they were made by a real interaction. They had successfully demonstrated the Breit-Wheeler process.

The researchers also measured the energy and the distribution of mass of the systems. "They are consistent with theory calculations for what would happen with real photons," Daniel Brandenburg, a physicist at Brookhaven, said in the statement.

Nonetheless, even if they appear to be behaving like real particles, the virtual photons used in the experiment are still undeniably virtual. This raises the question of whether the experiment was a true demonstration of the Breit-Wheeler process, but it's still an important first step until physicists develop lasers powerful enough to show the process with real photons.

The researchers published their findings July 27 in the Journal [Physical Review Letters.](https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.127.052302)

(Ben Turner / LIVESCIENCE, 16 August 2021, https://www.livescience.com/einstein-equation-matter-from-light?utm_source=notification)

Measurement of e^+e^- Momentum and Angular Distributions from Linearly Polarized Photon Collisions

J. Adam *et al.* (STAR Collaboration)

Abstract

The Breit-Wheeler process which produces matter and anti-matter from photon collisions is experimentally investigated through the observation of 6085 exclusive electron-positron pairs in ultraperipheral Au+Au collisions at √8NN=200 GeV. The measurements reveal a large fourth-order angular modulation of $\cos 4\Delta\varphi=(16.8\pm2.5)\%$ and smooth invariant mass distribution absent of vector mesons (φ, ω, and ρ) at the experimental limit of ≤0.2% of the observed yields. The differential cross section as a function of e^+e^- pair transverse momentum $P_\perp$ peaks at low value with $\sqrt{\langle P_\perp^2\rangle}=38.1\pm0.9$ MeV and displays a significant centrality dependence. These features are consistent with QED calculations for the collision of linearly polarized photons quantized from the extremely strong electromagnetic fields generated by the highly charged Au nuclei at ultrarelativistic speed. The experimental results have implications for vacuum birefringence and for mapping the magnetic field which is important for emergent QCD phenomena.

Phys. Rev. Lett. 127, 052302 – Published 27 July 2021

(https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.127.052302)

ΕΝΔΙΑΦΕΡΟΥΣΕΣ ΑΝΑΜΝΗΣΕΙΣ

Αλάσκα

Παύλος Μαρίνος

Η επίσκεψη έγινε 17 με 20 Οκτωβρίου 2010 (από Βοστώνη που ξεκινήσαμε, 7 ώρες Άνκορατζ/Φαιρμπάνκς)

Γράφθηκε 1 Αυγούστου 2021

29 Ιουλίου 2021, ισχυρός σεισμός, μεγέθους 8.2 Ρίχτερ, σημειώθηκε στα νότια της ακτής της Αλάσκας. Προειδοποίηση για τσουνάμι. Το USGS τον περιγράφει ως τον μεγαλύτερο σεισμό στις ΗΠΑ εδώ και 50 χρόνια.

Ο τωρινός σεισμός 8.2 του Ιουλίου 2021

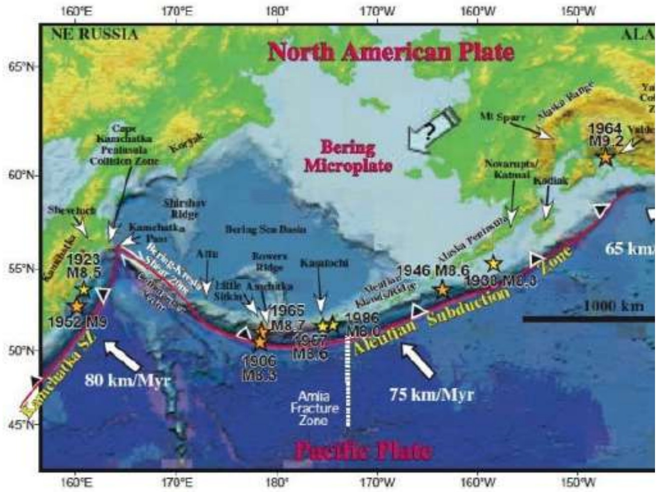
Και πριν 50 χρόνια; Πριν ήταν ο φοβερός σεισμός του 1964.

Ο «Σεισμός της Μεγάλης Παρασκευής», σημειώθηκε στις 5:36 μ.μ. ώρα Αλάσκας τη Μεγάλη Παρασκευή, 27 Μαρτίου 1964 Σε όλη την κεντρική-νότια Αλάσκα, μεγάλες ρωγμές κι αλλοιώσεις στο έδαφος, ρευστοποίηση εδάφους, κατολισθήσεις, γκρεμισμένα κτίρια, οικισμοί, υποδομές και τσουνάμι που προκάλεσαν 139 θανάτους (κυρίως από το τσουνάμι).

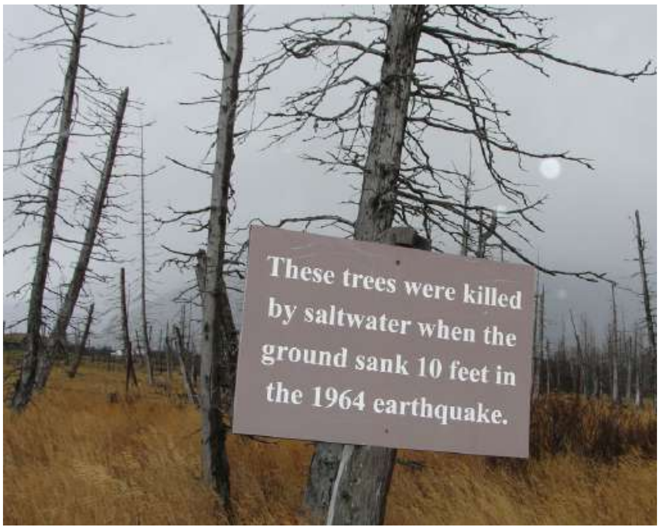
Η διάρκεια του σεισμού ήταν 4 λεπτά και 38 δευτερόλεπτα και το μέγεθος 9,2 Ρίχτερ. Ήταν ο πιο ισχυρός σεισμός που καταγράφτηκε ποτέ στη Βόρεια Αμερική, και ο δεύτερος πιο ισχυρός που έχει καταγραφεί στην παγκόσμια ιστορία, καθώς ο ισχυρότερος όλων των εποχών ήταν ο Μεγάλος σεισμός της Βαλδίβια (Χιλή, 1960) με 9,5 (από τότε που έχουμε καταγραφές). Το μέγιστο επίπεδο αντιληπτής έντασης του σεισμού, επίσημα, έφτασε στο επίπεδο έντασης XI της 12βάθμιας κλίμακας Μερκάλι, δηλαδή «ασύλληπτα καταστροφικός».

Σεισμός Αλάσκας, 1964. Μια πολύ γνωστή φωτογραφία στους περί τους σεισμούς

Ο σεισμός της Αλάσκας προήλθε από ανάστροφο ρήγμα. Ήταν ένας σεισμός σε ζώνη καταβύθισης όταν μια ωκεάνια πλάκα βυθίζεται κάτω από μία ηπειρωτική πλάκα. Το ρήγμα Aleutian Megathrust ήταν το υπεύθυνο. Πρόκειται για ένα τεράστιο ρήγμα -από τα μεγαλύτερα της Γης- που έχει μήκος 3.600 χιλιόμετρα και ξεκινά κοντά από την χερσόνησο της Kamchatka στην Ρωσία στα δυτικά και φθάνει στον κόλπο της Αλάσκας στα ανατολικά. Αποτελεί τη διεπαφή μεταξύ της βυθιζόμενης πλάκας του Ειρηνικού και της τεκτονικής πλάκας της Βόρειας Αμερικής Το ρήγμα μετά από μία οριζόντια μετατόπιση, έκανε μία ακολουθία πετρωμάτων να αποκολληθεί από τις ρίζες τις, να μετακινηθεί και να τοποθετηθεί πάνω σε κάποια άλλη (thrust). Ο σεισμός είχε εστιακό βάθος 25 χλμ. Η σεισμική δόνηση μετατόπισε τον ωκεάνιο βυθό δημιουργώντας ένα μεγάλο τσουνάμι που έφτασε σε ύψος 67 μέτρων. Επιπλέον παρατηρήθηκε παρακατακόρυφη μετατόπιση μέχρι και 11,5 μέτρα που επηρέασε μια ζώνη 250.000 km² στην ευρύτερη περιοχή της Αλάσκας. Έγιναν χιλιάδες μετασεισμοί για τρεις εβδομάδες, μετά τον Μεγάλο σεισμό της Αλάσκας. Την πρώτη ημέρα μόνο, 11 μεγάλοι μετασεισμοί καταγράφηκαν.



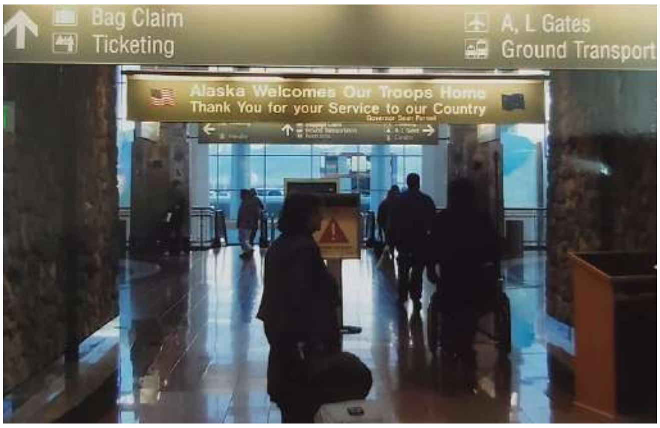
Το μοντέλο της συμπίεσης στην περιοχή. Δεξιά, ανατολικά, ο σεισμός του 1964 (πηγή Wikipedia)



Σεισμός 1964. Χωρίς λόγια. Φωτοφραφία δικιά μου του 2010 Trans-Alaska pipe line. Όλα τα μέτρα για ευκινησία προκειμένου ο αγωγός να συνεργασθεί με ασφάλεια σε μελλοντικό σεισμό. Και φραγμοί ασφαλείας για διακοπή της ροής.

Η επίσκεψη μας

Νάμαστε λοιπόν με την Κατερίνα στην Αλάσκα, στο Πανεπιστήμιο του Fairbanks, προσκεκλημένος για διαλέξεις.



Η υποδοχή στο Αεροδρόμιο. Των στρατιωτών, μάλλον από το Αφγανιστάν, που μόλις είχε αρχίσει την εμπλοκή της η Αμερική. Προσέξτε το ύφος της γραφής.

Η Αλάσκα είναι η μοναδική μη συνεχόμενη με άλλη πολιτεία των ΗΠΑ στην ηπειρωτική Βόρεια Αμερική. Τα χωρικά ύδατα της Αλάσκας αγγίζουν τα χωρικά ύδατα της Ρωσίας στο Βερίγγειο Πορθμό, καθώς το ρωσικό νησί Μεγάλος Διομήδης (!) και το νησί της Αλάσκας Μικρός Διομήδης (1) απέχουν μόνο 3,8 χλμ.

Βερίγγειος πορθμός και οι Διομήδιοι (!) νήσοι στην μέση (συγγνώμη που ο χάρτης δεν έχει κλίμακα αλλά τα δυό νησιά απέχουν 3,8χλμ μόνο) και η έκταση της Αλάσκας σε σύγκριση με τις άλλες πολιτείες

Η εξερεύνηση της Αλάσκας άρχισε το 1741 από τον Βίτους Μπέρινγκ (Βερίγγειο), για λογαριασμό της Ρωσίας. Τη συνέχισε το 1778 ο πανταχού παρών Τζέιμς Κουκ και στις αρχές του 19^{ου} αιώνα άλλες αποστολές, εξερεύνησαν τις ακτές από τον Ειρηνικό ως τον Βόρειο Παγωμένο ωκεανό. Η συστηματική εξερεύνηση της Αλάσκας και ο αποικισμός της που ακολούθησε οφείλονται κυρίως στους Σιβηριανούς και Αμερικανούς κυνηγούς, οι οποίοι ίδρυσαν εταιρίες για το κυνήγι ζώων και την πώληση γουναρικών.

Η Αλάσκα ανήκε στη Ρωσία μέχρι το 1867, χρονιά κατά την οποία πωλήθηκε στις ΗΠΑ, από τον τσάρο Αλέξανδρο Β' έναντι του ποσού των 7.200.000 δολαρίων. Μεγάλη κριτική, από τους Ρώσους γιατί δίνουν γη τους και κυρίως από τους Αμερικάνους στην κυβέρνηση τους που ξόδεψαν τόσα χρήματα.

Δεν άργησαν πάντως οι τελευταίοι να δούν ότι είχαν τελικά τραβήξει ένα πρώτο λαχνό. Πλούτος, πλούτος, φυσικός, στην επιφάνεια και κυρίως στο υπέδαφος.

Το 1959 η Αλάσκα ανακηρύχθηκε ως η 49$^{\eta}$ ομόσπονδη πολιτεία των Ηνωμένων Πολιτειών. Πρωτεύουσα το **Juneau**

Στην Αλάσκα συναντάται ποικιλία κλιματικών ζωνών. Στα Νότια το κλίμα είναι οριακά ψυχρό Ωκεάνιο, με σχετικά ψυχρούς χειμώνες χωρίς η θερμοκρασία να πέφτει κάτω από τους -15°C και αρκετά δροσερά καλοκαίρια χωρίς η θερμοκρασία να ξεπερνάει τους 23°C ενώ οι χιονοπτώσεις διαρκούν κυρίως από τον Οκτώβριο έως και τα μέσα Φεβρουαρίου. Στα βόρεια το κλίμα είναι πολικό και η θερμοκρασία πολλές φορές πέφτει κάτω από τους -40°C ενώ το καλοκαίρι η θερμοκρασία δεν ξεπερνάει τους 10°C και επικρατεί παγετός έως τις αρχές του Ιουλίου. Οι ακραίες θερμοκρασίες που έχουν καταγραφεί στην Αλάσκα είναι 38 °C και −62 °C .

Οι **Αλεούτιες νήσοι** είναι περισσότερα από 300 μικρά ηφαιστειακά νησιά σχηματίζοντας μια τοξοειδή αλυσίδα η οποία εκτείνεται σε απόσταση 1.900 χιλιομέτρων στον Ειρηνικό Ωκεανό. Ορισμένα από αυτά τα νησιά πέφτουν στο ανατολικό ημισφαίριο, αλλά η Διεθνής Γραμμή Ημερομηνίας (International Date Line) σχεδιάζεται δυτικά των 180° για να κρατήσει ολόκληρη την πολιτεία, και έτσι ολόκληρη τη βορειοαμερικανική ήπειρο είναι εντός της ίδιας ημερομηνίας. Δύο από τα νησιά καταλήφθηκαν από τις ιαπωνικές δυνάμεις κατά τη διάρκεια του Β' Παγκοσμίου Πολέμου.

Το **Anchorage** είναι η μεγαλύτερη πόλη προσφέροντας τις κλασσικές ανέσεις μιας Αμερικανικής πόλης, οντας και δίπλα στην άγρια φύση. Καταστράφηκε από τον σεισμό της «Μεγάλης Παρασκευής» του 1964. Γρήγορα ανορθώθηκε από το μπουμ του πετρελαίου[1]. Εδώ και στα γύρω ζει μακράν ο πολύς πληθυσμός της πολιτείας, περίπου 290.000. Η πολιτεία γύρω στα 740.000 (2018). Το Άνκορατζ αποτελεί την οικονομική και πολιτική καρδιά της Αλάσκα.

Άνκορατζ, η μεγαλύτερη πόλη της Αλάσκας

Το **Fairbanks**, στο εσωτερικό της Αλάσκας, μια απλωμένη και χαμηλού ύψους πόλη, έχει ακραίες κλιματικές συνθήκες που μπορεί να φθάσουν και κάτω από -40^0 τον χειμώνα και γύρω στα 21^0 το καλοκαίρι, περιπτωσιακά στα 30^0. Αναπτύχθηκε στην αρχή του περασμένου αιώνα όταν βρέθηκε χρυσός στην περιοχή. Σήμερα έχει περί τις 100.000 κατοίκους. Το πιο μεγάλο μέρος της περιφέρειας είναι ακατοίκητο. Εδώ το Ντενάλι, το υψηλότερο βουνό στη Βόρεια Αμερική, με κορυφή 6.190μ.

Χρυσωρύχοι και μεταλλοδίφες σε πορεία αναζήτησης κατά την περίοδο του πυρετού του χρυσού[2]

Στον 2^{ο} Πόλεμο, με βάση το αμερικανικό πρόγραμμα παραχώρησης, αρκετά αεροπλάνα μεταφέρθηκαν από τον Καναδά στο Φέρμπανκς της Αλάσκας, για να δοθούν σε πιλότους του σοβιετικού στρατού και στη συνέχεια να χρησιμοποιηθούν για την απώθηση της γερμανικής εισβολής στη Σοβιετική Ένωση.

Το απαραίτητο Ελληνικό εστιατόριο και στο Φέρμπανκς (Boby's, Χαράλαμπος). Το τζατζίκι ξεχείλιζε αλλά και η ευγένεια του Χαράλαμπου. Αφήσαμε ελληνικά βιβλία που είχαμε για διάβασμα στα ταξίδια. Να και το εσκιμωάκι

Ιδιαίτερου κύρους πανεπιστήμιο της πολιτείας είναι εδώ, στο Φέρμπανκς, το Πανεπιστήμιο της Αλάσκας, κρατικό. Εδώ ήμουν καλεσμένος.

Έτοιμη η αίθουσα για μια από τις διαλέξεις

[1] Το 1968 ανακαλύφθηκαν κοιτάσματα πετρελαίου στον κόλπο Προύντο, ενώ το 1977 ολοκληρώθηκε ο αγωγός Τρανς-Αλάσκα ξεκινώντας μία νέα εποχή «πυρετού του πετρελαίου» στην πολιτεία. Το 1989 το ατύχημα του δεξαμενόπλοιου Έξον Βαλντέζ, το θυμόμαστε, προκάλεσε τη διαφυγή περίπου 40.000 τόνων αργού πετρελαίου σε μία πετρελαιοκηλίδα που εξαπλώθηκε σε περισσότερα από 1600 χιλιόμετρα ακτογραμμής. Το γεγονός αυτό αποτέλεσε μία από τις πιο μεγάλες οικολογικές καταστροφές στον πλανήτη, αλλά παράλληλα και ένα ορόσημο για τα μέτρα ασφάλειας της ναυτιλίας.

[2] Θυμάστε την ταινία «Ο Χρυσοθήρας» του Chaplin;

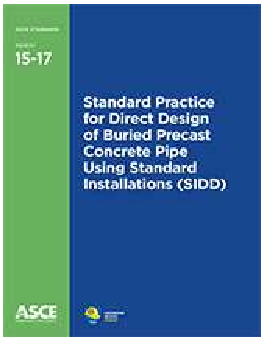
Permafrost

Η αφεντιά μου σε στοά μεταλλείου σε ζώνη permafrost

Κατά την επίσκεψη μου στο Φέρμπανκς, επισκέφθηκα και ένα εξοφλημένο μεταλλείο χρυσού, όχι μεγάλου βάθους. Ο χρυσός είχε μαζευτεί από την διάβρωση της πρωτογενούς εστίας του και ανακατευτεί με τις προσχώσεις. Οι προσχώσεις, αμμοχάλικα χωρίς καμιά σύνδεση μεταξύ τους (συνοχή), όπως φαίνεται στην φωτογραφία. Και όμως στέκονται χωρίς να κατάκρημνίζονται. Απίθανη εικόνα εε! Αναζητείστε μικρούς υμένες πάγους ανάμεσα στα χαλίκια. Είμαστε στη ζώνη του permafrost! Έτσι και τα φυσήξεις με ζεστό αέρα, κάτω όλα.

«Αγάπη είσαι για ένα τάνγκο»

ΝΕΕΣ ΕΚΔΟΣΕΙΣ ΣΤΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΠΙΣΤΗΜΕΣ



Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

American Society of Civil Engineers, ASCE/CI 15-17

Prepared by the Direct Design of Buried Concrete Pipe Box Sections Standards Committee of the Construction Institute of the American Society of Civil Engineers

Standard ASCE/CI 15-17 focuses on the direct design of buried precast concrete pipe using standard installations, known as SIDD. The direct design method improves on indirect design, because direct design accounts for the soil pressure distribution around an installed pipe and provides a procedure for determining the pressure distribution coefficients for the standard installations.

Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations reviews the design and construction of the soil–pipe interaction system used for the conveyance of sewage, industrial wastes, stormwater, and drainage. The SIDD method accounts for the interaction between pipe and soil envelope in determining loads, pressure distributions, moment, thrust, and shear. Construction requirements for excavation, safety, foundations, bedding, sheathing removal, and trench shield advancement are presented. Four types of standard embankment installations and four types of standard trench installations are covered. This Standard, a revision of ASCE 15-98, includes updates to correlate with the latest ASTM International and American Concrete Pipe Association (ACPA) documents for trench and embankment conditions, as well as current soil classifications. Design equations for nonreinforced concrete pipe have been added.

Standard ASCE/CI 15-17 may be used as a reference in preparing project specifications based on the SIDD method, and the limits state design procedure is consistent with the procedures outlined in the AASHTO *Standard Specifications for Highway Bridges*. This Standard is useful to civil engineering design professionals, consultants, owners, and transportation officials.

(https://ascelibrary.org/doi/book/10.1061/9780784413074)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

International Journal of Geoengineering Case Histories

An official journal of the International Society for Soil Mechanics and Geotechnical Engineering

Volume 6, Issue #2, https://www.geocasehistoriesjournal.org/pub/issue/view/48

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