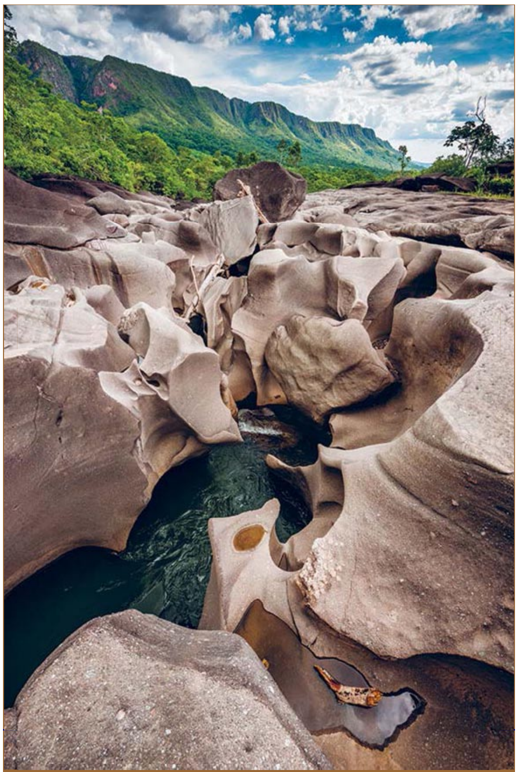
ΕΛΛΗΝΙΚΗ
ΕΠΙΣΤΗΜΟΝΙΚΗ
ΕΤΑΙΡΕΙΑ
ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ
& ΓΕΩΤΕΧΝΙΚΗΣ
ΜΗΧΑΝΙΚΗΣ



Brasil

116

. 116 – 2018

Innovative scientific methodologies and challenging projects marking future tren tural heritage, have initiated a universal conversation within a holistic approach, merging capabilities and know how from the scientific fields of architecture, civil

(3)

(συνέχεια από την πρώτη σελίδα)

engineering, surveying engineering, materials science and engineering, information technology and archaeology, as well as heritage professionals on restoration and conservation and policy makers in cultural heritage. The combined utilization of digital documentation technologies with innovative analytical and non-destructive techniques, computational and digital techniques and archaeometric methods supports the creation of a transdisciplinary multispectral modelling towards the sustainable preservation of cultural heritage. Innovation is enhancing and revealing a critical dimension of the preservation of cultural heritage along with social participation and communication.

The National Technical University of Athens interdisciplinary team "Protection of monuments" [Prof. A. Moropoulou, Prof. Emer. M. Korres, Prof. A. Georgopoulos, Prof. C. Spyrakos, Ass. Prof. C. Mouzakis], scientific responsible for the Holy Aedicule's rehabilitation of the Holy Sepulchre in Jerusalem, and the Technical Chamber of Greece, in collaboration with the Ministry of Culture and Sports and the Ministry of Digital Policy, Telecommunications and Media of the Hellenic Republic, organize the **1st International Conference on "TRANSDISCIPLINARY MULTISPECTRAL MODELLING AND COOPERATION FOR THE PRESERVATION OF CULTURAL HERITAGE" [TMM_CH]** on 10-13 October 2018, in Athens, Greece, discussing modern trends in the original agora of our technological and democratic roots.

TMM_CH international conference is organized under the auspices of H.E. the President of the Hellenic Republic, with the support of the Hellenic Parliament, in cooperation with the National Geographic Society, World Monuments Fund, ICOMOS, European Construction Technology Platform, European Society for Engineering Education SEFI, and other major international and European organizations, associations and networks in the field of cultural heritage preservation.

The conference will be held at the Eugenides Foundation, with reference to the Digital Exhibition of Advanced Technology "Tomb of Christ: the Monument and the Project" at the Byzantine and Christian Museum of Athens [21 May 2018 until 31 January 2019]. Scientific walk and talk visits to Acropolis and Ancient Agora [in the footsteps of the Greek Peripatetic Philosophical School] and other major archaeological sites are planned on 13 October 2018.

The International Steering Committee and the International Scientific Committee welcome research contributions for oral and poster presentations in English. The submitted abstracts and papers will be peer reviewed. Accepted papers will be divided into sessions. Plenary lectures [after invitation] will cover major accomplishments, trends and technical challenges. Please check important dates for submission deadlines.

Selected papers will be published in Springer Computer Science Proceedings, available in 2018 following the Conference.

ORGANISERS

- National Technical University of Athens
- Technical Chamber of Greece

IN COLLABORATION WITH

- Ministry of Culture and Sports of the Hellenic Republic
- Ministry of Digital Policy, Telecommunications and Media of the Hellenic Republic

GREEK NETWORK FOR TRANSDISCIPLINARY MULTISPECTRAL MODELLING AND COOPERATION FOR THE PRESERVATION OF CULTURAL HERITAGE

- National Technical University of Athens
- Panteion University of Social and Political Sciences
- University of Piraeus
- Aristotle University of Thessaloniki
- University of Patras
- University of Ioannina
- Technical University of Crete
- Democritus University of Thrace
- University of the Aegean
- Ionian University
- University of Thessaly
- University of the Peloponnese
- University of West Attica
- School of Pedagogical & Technological Education

UNDER THE AUSPICES

- H.E. the President of the Hellenic Republic

WITH THE SUPPORT

- Hellenic Parliament

Κατά την διάρκεια του συνεδρίου προβλέπεται η διεξαγωγή Ειδικής Συνεδρίας με θέμα **Γεωτεχνική Προσέγγιση της Προστασίας Μνημείων**, με συντονιστές τα μέλη της ΕΕΕΕΓΜ Μιχάλη Καββαδά, Παύλο Μαρίνο, Χρήστο Τσατσανίφο και Βασίλη Χρηστάρα. Καλούνται τα μέλη της ΕΕΕΕΓΜ να συμμετάσχουν στην Ειδική Συνεδρία με την υποβολή άρθρων. Η προθεσμία υποβολής θα είναι διαφορετική από αυτήν των άρθρων του κεντρικού συνεδρίου και θα ανακοινωθή συντόμως.

ΑΦΙΕΡΩΜΑ ΣΤΑ ΦΡΑΓΜΑΤΑ – ΑΣΦΑΛΕΙΑ ΦΡΑΓΜΑΤΩΝ

Using Correlation Plots for Dam Safety Analysis

Eugene B. Gall

Social MediaTools

Preparing correlation plots – which involve plotting two or more variables against each other rather than against time – is a useful way to analyze data collected by dam safety monitoring devices. Correlation plots are particularly useful for monitoring dams where reservoir water levels vary significantly.

Proper instrumentation plays an important role in monitoring the safety of a dam. Equally important is proper interpretation of the data collected by the instrumentation. The two primary ways to plot instrumentation data with regard to a specific stimulus (such as reservoir level) are:

- On the same axis with the stimulus, against time (producing a time-history plot); or
- Against the stimulus (producing a correlation plot).

Typically, personnel produce time-history plots of various data, such as piezometer level and reservoir water level for embankment dams. However, this practice gives rise to several questions:

- Does this type of plot provide all the information available from the data?
- Should the dam owner select threshold/action levels based on slope stability, historical readings, or both?
- If the reservoir at a pumped-storage project is at a low level or even mid-level, how does the project owner evaluate safety of the embankment dam after an earthquake? What is the threshold level in this case?

The above questions can be answered by plotting and interpreting the correlation between the reservoir water level and piezometer level. Correlation plots generally are underutilized because, in most cases, the behavior of the dam is clear enough on the time-history plot, especially for a reservoir with a quasi-constant level. However, correlation plots illustrate some aspects of the piezometric response of embankment dams better than time-history plots. Correlation plots are a valuable tool and are regularly used by some organizations,[1,2,3] but they are not used as often as they should be. Under the right circumstances, correlation plots can be indispensable in analyzing data gathered from instrumentation.

Correlation plots can be used in many simple applications, including identifying stimulus and evaluating piezometer clogging.[1,4]

Understanding correlation plots

Conventional correlation plots present the reservoir water level along the x-axis and the piezometer level along the y-axis. Each point on the correlation line is a piezometer/reservoir reading, taken at a moment in time, which does not necessarily represent the steady-state condition. If the piezometer level is influenced only by the reservoir water level and no significant lag effect is present, the plot shows a straight line. In general, the larger the distance or gradient between the piezometer and the reservoir, the weaker the correlation and the flatter the slope. Mathematically, the limit cases are:[4]

- Full correlation for a piezometer connected to a reservoir, when the piezometer reading equals the reservoir level, is represented by a 45-degree line for equal scales on both axes; and
- No or zero correlation, with a horizontal line representation, when the piezometer level is constant regardless of the reservoir level.

If the piezometer is influenced by and thus lags behind the reservoir level when it rises or falls, the points scatter along a sloped line (correlation line). On correlation plots, the lag for a certain reservoir level is expressed as the deviation in piezometer level from the correlation line. It is expressed in feet, rather than in time (as it is on the time-history plot).

Alternately, random scattering along a constant piezometer value for constant reservoir level shows that a different stimulus exists (such as runoff, aquifer fed from an uphill source, or tailwater level variation) that may need to be identified.

Correlation plots are especially sensitive to several factors. These are:

- Changes in the piezometric regime. Any new development or action that significantly affects the cause or effect of a correlation requires building a new correlation plot. Factors affecting both the phreatic line in the dam or foundation (i.e., grouting, installation of dewatering wells, etc.) and the piezometer itself (i.e., flushing, recalibration, etc.) are examples of such changes.
- Instrumentation data collection errors. If the reservoir and piezometer levels are not recorded at the same time, this time gap will be interpreted as an additional (but false) lag and will lead to an incorrect correlation. This interval depends on the rate of variation of the reservoir level. This is especially important for relatively rapid reservoir level variation, as in pumped-storage projects where a variation of several feet per hour is common.
- The "scale" effect. Selection of a too-detailed scale for piezometer readings visually exaggerates the reading variation and may mislead the reader into believing that a correlation exists.

Using correlation plots

The use of correlation plots is particularly helpful when analyzing data from instrumentation at storage and dewatered projects, at pumped-storage projects, and when monitoring potential failure modes (PFMs).

Storage and dewatered projects

Complex monitoring is required at projects that store water, during initial filling of a reservoir, or during dewatering and refilling of a reservoir at a run-of-river plant. These situations call for the use of correlation plots in addition to history plots.

Take the example of an embankment dam on glacial till with a central core. The reservoir impounded by the dam was being dewatered to repair the embankment. Monitoring was necessary for two situations:

- Uncontrolled reservoir level rise due to floods while repairs were being completed; and
- Controlled slow refilling of the reservoir after repairs were completed. The average rate of refill was 0.14 foot per

day, and the piezometers were allowed to stabilize at intermediate stages.

Monitoring was complicated by flushing of the old standpipes (some of them were partially clogged) and installation of dewatering wells at the toe of the dam. These activities improved responsiveness of some piezometers and lowered the phreatic line through the dam, respectively. Not all piezometers were affected by these activities, but new correlation plots had to be reconfigured after each modification for the ones that were affected. These plots had to use only the post-modification data collected during several floods that occurred in the dewatering interval and during refill operation.

The correlation plots for piezometers in pervious layers (clean sand, in this case) directly connected with the reservoir were relatively simple. They exhibited a sloped straight-line plot, meaning they were clearly influenced by the reservoir. The apparent lag is zero for all practical purposes.

The correlation plots for piezometers in low-permeable or impervious layers were more complex. Figure 1 shows the response for a standpipe in the silty core of the embankment dam, along the centerline. The piezometer level drops only 2 feet during a 50-foot rapid reservoir dewatering from the initial steady-state point A (full reservoir) along line AB. The piezometer drops another 9 feet toward a second steady-state point C (under stationary dewatered reservoir) along line BC. Then the plot shows a slow-refill correlation (line CA) that includes stabilization at each refill stage.

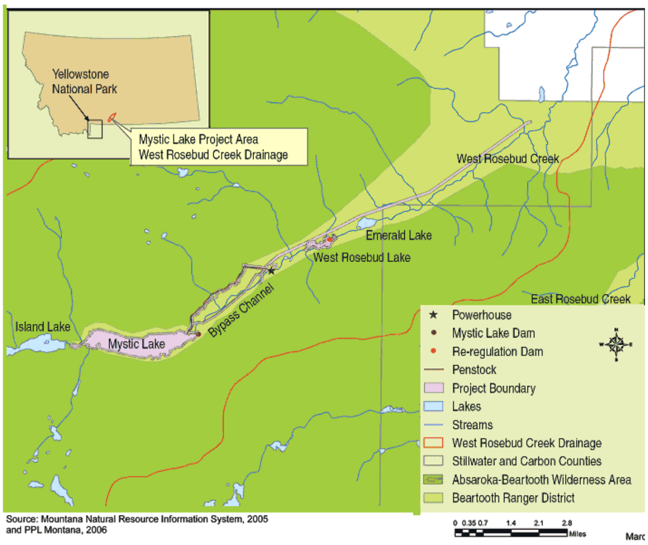


Figure 1: *During rapid reservoir dewatering from Point A to Point B, the piezometer level drops only 2 feet. When dewatering is completed, the piezometer level drops another 9 feet to Point C. Points A and C are representative for steady state in full and dewatered reservoir condition, respectively. The piezometer readings then show good correlation with reservoir level (from C to A) as the reservoir is slowly refilled. Although the red and green loops representing flash floods during refilling fall below the orange envelope of the CA correlation, these readings do not indicate an abnormal development but rather a faster rate of refill.*

The readings part of the CA correlation could be contained either between two straight lines or within a closed envelope. I prefer to use an elliptical visually-determined "best fit" envelope because it highlights the smaller range of the piezometer readings variation that corresponds to the lower rate of reservoir variation for the extreme levels. The "loops" below line CA are due to the 2006 and 2007 floods when the piezometer could not keep up with the fast-rising reservoir level and dropped below the correlation envelope. These readings are outside of the "normal" operation envelope but do indicate a fast rate of reservoir variation rather than an adverse development. Any readings outside the envelope should be carefully evaluated before any action is taken.

The correlation plot shows at a glance the consistency and accuracy of the correlation, the historical range of the piezometer readings, and the deviation of the current reading for any reservoir level. The history plot does not offer this information.

Pumped-storage projects

The piezometer lag is somewhat easier to recognize on a

time-history plot for a pumped-storage project because the reservoir reaches the same elevation several times a week and the corresponding piezometer levels can be compared. However, one still cannot accurately quantify this lag and recognize incipient negative trends at a glance.

For pumped-storage projects, the piezometer readings perform daily loops inside a well-defined envelope, specific for each rate of reservoir variation depending on the number of units running. For these correlation plots, the visual best-fit elliptical envelope is used again. The slope of the longitudinal axis of this ellipse shows the degree of correlation, and the vertically-measured range is twice the instantaneous lag for each water level.

Note that, due to variation in reservoir level of up to 40 feet in several hours at pumped-storage projects, piezometer readings represented by the points on the correlation plot do not necessarily correspond to the steady-state level for that reservoir level. Deviation from the equilibrium line is generally smaller for piezometers in pervious layers and larger for piezometers in impervious layers.

The behavior of two piezometers in the lower embankment of a pumped-storage project (see Figures 2 and 3) illustrates the characteristics of correlation plots produced. Readings and plotting were done under both normal pumped-storage operation and full lower reservoir held under constant level while the upper reservoir was dewatered for inspection and repairs. This dewatering lasted a couple of months, and the steady state for full lower reservoir was attained for all practical purposes.

Figure 2 shows a correlation plot for a vibrating wire piezometer in a clean sand aquifer in the dam foundation, at the toe of the lower embankment. During the normal weekly pumped-storage operation, the reservoir level varies 37 feet and the piezometer level 13 feet.

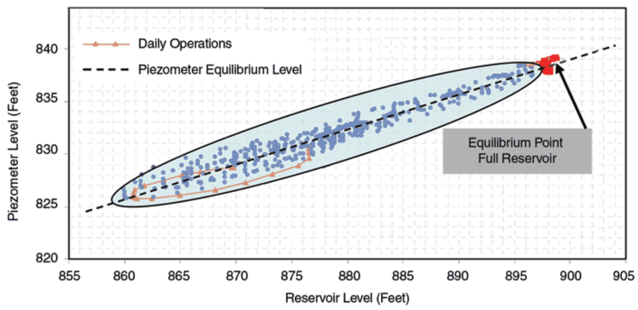


Figure 2: *This correlation plot for a vibrating wire piezometer in a sand aquifer in the dam foundation, at the toe of the lower embankment, shows the reservoir level varies by 37 feet and piezometer level varies by 13 feet during normal weekly operation at this pumped-storage project. When the reservoir was held constant at maximum level and reached the steady state, the piezometer level aligned well within the longitudinal axis of the normal operation envelope (pale blue), indicating that the correlation is representative for both steady-state and normal operating condition.*

The piezometer stabilized fast once the reservoir was held under constant level, with an apparent increment in piezometer level of only several inches. The piezometer equilibrium level aligns well with the longitudinal axis of the normal operation envelope, which, for this case, can be considered representative for both operation and steady-state conditions.

Applications of this plot are:

– A benchmark for future readings;

– A benchmark for checking dam condition after a major

event, such as an earthquake, regardless of the reservoir level. This is based on the location of the piezometer reading at that time on the correlation plot, i.e., in or out of the plotted ellipse representing the expected or historical range for that particular reservoir level.

– A determination of water pressure in an aquifer in the dam foundation at the toe during floods, to be used in calculation of heaving or lifting safety factor for the impervious layer that covers the aquifer. This is done by extrapolation of the correlation line and reading for flood reservoir level. (This is valid only for piezometers in pervious material.)

– A benchmark for prolonged high water level in the lower reservoir while the upper reservoir is dewatered for inspection and/or repairs. (This is valid only for piezometers in pervious material.)

Figure 3 shows a correlation plot for a hydraulic piezometer in the clay core of the embankment at the same pumped-storage project, for the same time period. It took about a month from when the reservoir level was held constant until this piezometer reached the steady-state level. The piezometer level increment from apparent equilibrium to steady-state level was about 10 feet. This point falls way out of the normal operation correlation envelope that, in this case, is representative for piezometer only in "standard" pumped-storage operation but not for the steady-state condition. The points inside the envelope are "floating" with the reservoir level, but they are not stabilized for any particular level.

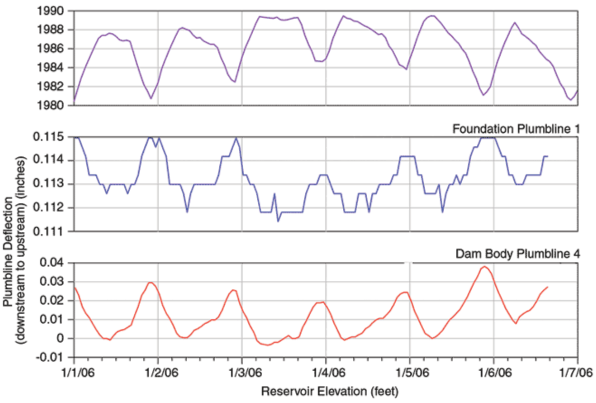


Figure 3: *This correlation plot for a hydraulic piezometer in the clay core of the embankment at the same pumped-storage project described in Figure 2, for the same time period, indicates the equilibrium point, when the reservoir level was held constant. This point falls well outside the normal operation envelope (pale blue), meaning that the piezometer readings during normal operation are "floating" with the reservoir level but the steady state is never reached.*

Applications of this correlation plot for a piezometer in an impervious layer include use as a benchmark for readings during both regular inspections and inspections after a major event, regardless of the reservoir level.

Another recent application was initiated by elevated readings at a couple of piezometers at the toe of the upper sealed reservoir of a pumped-storage project. The project did not have an automated data acquisition system. The reservoir levels were not routinely recorded at the time of reading of piezometer levels, so correlations could not be obtained from the historic data. A three-day hourly recording of simultaneous piezometer and reservoir levels under 40 foot daily variation supplied data necessary to produce correlation plots for all piezometers. It was found that the elevated piezometers did not respond to the reservoir level variation, and a different stimulus was identified. However, three other piezometers did, so apparently the reservoir seal was leaking at a location in the general area of these piezometers.

When the reservoir was dewatered, several cracks were found in the reservoir floor liner. Although this trend could be seen in the time-history plot, it was more evident in the correlation plot.

Monitoring PFMs

A more general application involves the presentation of threshold levels against the reading data for monitoring PFMs. The threshold level is a reading that indicates a significant departure from the normal range of readings and prompts an action.[5] (However, exceeding the threshold by itself usually does not imply an instability of the structure.) Multiple thresholds sometimes are designated in relation to the same failure mode.

The threshold levels are routinely determined based either on position of the actual pore pressure level relative to the level considered in the slope stability calculation, or the deviation from the historical readings. However, the design limit (design basis value5) corresponds to only one particular reservoir level, i.e., the level considered in a stability calculation. In addition, the historic limit cannot be easily read on a time-history plot for a specific reservoir level. In fact, each approach covers a different failure mode and these approaches can be represented, read, and interpreted on the correlation plot as a unitary concept (see Figure 4). The more complex plot for a piezometer in the pumped-storage clay core embankment (shown in Figure 3 on page 65) was used for illustration, and the origin of the threshold is labeled.

Figure 4: *Correlation plots can be used to present threshold levels against the piezometer and reservoir levels for monitoring potential failure modes (PFMs). This plot uses the data from Figure 3 to compare readings against three different PFMs. By using this plot, one can identify out-of-range piezometer readings for a certain reservoir elevation (but still in the general historical range), especially at the extreme reservoir level. In addition, Potential Failure Mode 2 and 3 readings indicate adverse developments that do not exceed the slope stability threshold.*

Note that there are out-of-range readings on Figure 4, labeled as Potential Failure Mode 2 and Potential Failure Mode

3. These are related to specific PFMs that could be identified only by their deviation from the historical range of readings, and they do not exceed the level used in stability calculations. In Potential Failure Mode 2, the penstock leakage pressurizes the core in the zone of influence of the piezometer without reaching the design limit (at least in the incipient stages). In Potential Failure Mode 3, piping developing in the zone of influence of the piezometer will not exceed the stability threshold limit and even drop below the correlation envelope as long as the pipe behaves like a drain, lowering the pore pressure. The advantage of the correlation plot is that abnormal readings that may indicate development of an adverse condition could be instantly visualized for any reservoir level.

Conclusions

Correlation plots are essential in evaluating the behavior of an embankment dam where reservoir levels are not constant, such as at storage projects and at projects during dewatering and filling. They clearly define the piezometric range of readings for any reservoir level (unlike time-history plots) and consequently allow for a better evaluation of action levels. Consequently, correlation plots are an ideal tool for evaluation of the embankment during both regular inspections and inspections after unusual events, such as floods and earthquakes.

Correlation plots also are useful in evaluating performance of weirs, slope inclinometers, and crack monitors.

Mr. Gall may be reached at Federal Energy Regulatory Commission, New York Regional Office, 19 West 34th Street, Suite 400, New York, NY 10001; (1) 212-273-5950; E-mail: eugene.gall@ferc.gov.

The examples and statements in this paper are based on the author's 15 years of experience with projects located in the northeastern U.S. under the jurisdiction of FERC.

Notes

1. Guidelines for Instrumentation and Measurements for Monitoring Dam Performance, American Society of Civil Engineers, Reston, Va., 2000.

2. Kuperman, Selmo C., M. Regina Moretti, Julio C. Pinfari, and Edvaldo F. Carneiro, "Placing 'Limit Values' on Instrument Readings," HRW, Volume 15, No. 3, July 2007, pages 24-31.

3. Harris, Craig, and Alex Grenoble, Instrumentation and Monitoring Training Classes for the Division of Dam Safety and Inspections, Federal Energy Regulatory Commission, Washington, D.C., 1996.

4. Gall, Eugene B., "Correlation Plot – A Modern Tool in Dam Safety Monitoring," USSD Annual Meeting and Conference, United States Society on Dams, Denver, Colo., 2007.

5. Engineering Guidelines for the Evaluation of Hydropower Projects, Chapter 14, Appendix J, Federal Energy Regulatory Commission, Washington, D.C., 2008.

Eugene Gall, P.E., is a dam safety engineering supervisor in the New York Regional Office of the Federal Energy Regulatory Commission.

(Hydro Review, Vol. 27, Issue 3, June 2008, http://www.hydroworld.com/articles/hr/print/volume-27/issue-3/technical-articles/using-correlation-plots-for-dam-safety-analysis.html)

Safe Dams are Based on Strong Data

Robert B. Jansen

Social MediaTools

Dam owners and engineers have access to a variety of ad-vanced analytical tools for assessing the safety of a dam. When using these tools, it's important to remember that a mathematical tool is only as good as the data that supports it. Each dam site and its environment is unique, with different characteristics governing performance. This requires sensibly interpreting specific site conditions and their effect on dam safety.

The survival of most dams suggests that their engineering has been amply conservative – or that their worst trials are yet to come. However, the level of conservatism in the design of an individual dam cannot be determined without a verified comparator. The ultimate measure is actual behavior under extreme forces.

Now armed with capable software and hardware, analysts are encoura ed to use these tools to re ine dam desi ns. In pur-suing this opportunity, they must give attention to the re-maining sources o error, lar el in the dam site and its en-virons. Improved skills enable analysis of features that could not be quantified previously, making possible more realistic representation of structural and foundation elements. This requires enou h investi ation to determine the characteris-tics that will govern dam performance, as well as the degree and e tent o deterioration to be anticipated. En ineers at-tracted by the intricacies of some numerical procedures must be continuously aware o the need to relate them to real con-ditions sensibly interpreted.

Most dam disasters can be attributed to overlooked or mis-understood pro ect laws and or underestimated loods. No-table dam failures include:

- Taum Sauk in Missouri in 2005: Overtoppin , mi sopera-tion, and weak rockfill and foundation contact.
- Nahal Oz in Israel in 2001: Fill breached by erosion of soils with unrecognized deficiencies.
- Teton in Idaho in 1976: Internal erosion o ill without il-ter; unsealed foundation rock joints.
- Frias in Argentina in 1970: Overtopping of rockfill, which was sealed on both faces without internal drains.
- Baldwin Hills in California in 1963: Leakage through fill and foundation cracks from land subsidence.
- Malpasset in France in 1959: Arch collapse throu h oun-dation rock displacement.
- Vega de Tera in Spain in 1959: Breakaway of buttresses of flat-slab dam due to poorly bonded joints.
- St. Francis in California in 1928: Gravity dam ruptured upon washout of very weak foundation rock.

Extracting value when limited data are available

For some dams where field and laboratory investigations have been limited, engineers have conducted sensitivity studies to draw the boundaries of possible dam behavior and to assess the relative influence of key parameters. For these analyses, various combinations of assumed data are used to weigh potential dam and foundation reactions to loadings, and thus to estimate the level at which structural capacity might be exceeded. For sites that do not appear to present interpretive challenges or aspects that might suggest the possibility of hidden problems, this type of analysis has been considered helpful in spanning information gaps.

Sensitivity analysis may be especially useful in analyzing older concrete dams with incomplete records and/or for which only rudimentary exploration and testing were done. Concrete structures have an importa posites of integral blocks able to bridge defects and thereby continue as intact units. In contrast, earth embankments cannot tolerate weakening of individual constituents without risking loss of the whole. Therefore, sensitivity analysis is more suitable for concrete sections that may have substantial ranges of unit strength but averages above an acceptable threshold.

Unknown conditions are not always detrimental. Curtailing exploration and testing might offer false economy if better knowledge of site assets could permit refinement of designs that otherwise would need to be excessive to compensate for lack of data. The difficulty of the search is not a valid excuse for lesser effort that leaves critical conditions in doubt.

Deficiencies that escaped attention during investigation and construction may be revealed once a dam is placed in service. To ensure detection early enou h or remedial act uous monitoring must be conducted by seasoned observers who know the signs of abnormal behavior. Dams that have bene ited rom timel response to s age surges, or other disorders include WAC Bennett in British Columbia, ontenelle in omin , a gan Martin and Walter Bouldin in Alabama, Matahina in New Zealand, Navajo in New Mexico, New Exchequer in California, and Willow Creek in Montana.

Factors that affect dam behavior

Several factors affect the behavior of a dam, among them loads, slope conditions, and structural capability of concrete dams.

Loads

When a dam has been in service long enough to adjust to normal loading under a fully established seepage regime, it has demonstrated its capability under those conditions. As time passes, chan es occur that a vorably or unfavorably. Benefits may accrue from seasoning of an embankment or the continuing increase in strength of concrete. Detriment may be caused by erosion of soils and soft rock in embankments and foundations or by cement leaching or alkali-aggregate reactivity. Normal operation may not test a dam unless its structural capacity is reduced by degradation or loss of materials.

Transient effects of natural events are less predictable. Nonovertopping surcharges from floods generally put only moderate incremental load on a structure. The most severe condition ma be caused b seismic cantly different multidirectional pounding at var in ampli tude and re uenc . ractures could cation of acceleration at higher levels in the dam. Seismic vibration is likely to be most dangerous at interfaces that may separate, as at structural or foundation contacts and at joints. Shaking at contact surfaces may initiate or extend cracks, as well as open and close gaps and result in variations in internal water pressures. These conditions can be modeled mathematically by increasingly sophisticated methods that take into account the dam and foundation units that might participate in destabilization.

Mathematical models have been used ble behavior of a dam under various loadings. Three-dimen-sional nonlinear finite-element analysis allows more detailed consideration o eatures that were to culation by the oversimplified practices common in earlier times. The interaction of a dam and its foundation and structural interfaces can be approximated if actual site characteristics are known sufficiently. However, complicated models that combine detailed structural components with poorly defined boundary elements may be of questionable value. Nonessential factors must be de-emphasized while clarifying those that have greatest influence on performance. For unassailable validation, particularly of structures on complex foundations, extensive tests in the laboratory and in situ may be needed to supplement thorough exploratory effort.

Advocates of state-of-the-art analysis say old methods may find a dam to be substandard when it is not. The same might be said for new methods. Also, either the old or the new might indicate a dam is safe when it is not. Such appraisals must be scrutinized to be sure they properly reflect the character of the dam and its environs and the potential damaging forces. In the case of extreme earthquake, the release and attenuation of energy from ground movement might be beyond confident prediction even if the location of the source is known. Analysis is complicated further by the scanty records from observation and measurement of dam reaction to severe seismic effects.

Reality checks that have been made by comparison of computed and actual dam performance have raised doubts about some numerical models. Criticism has been related less to theory and process than to lack of demonstrably representative data. In one illustrative case, retrospective finite-element analysis was made of a well-instrumented and extensively tested earth dam that withstood a strong earthquake with known acceleration at the site.

The chute spillway on Middle Fork Dam in California, an embankment dam, collapsed because of faulty underdrainage. Hydraulic conduits that are constructed on or that adjoin earthfills may be susceptible to deformation and damage by high flows.

The dam's calculated settlement and pore-water pressure rise during the event were several hundred percent higher than measured values. In examining these grossly misleading results, consideration was given to recalculation by adjusting the assumed embankment stiffness and degree of saturation. The effect of this recalculation would be to calibrate the mathematical model to the observed dam response. The hope was that the revised model then might be of some value in predicting performance in a greater earthquake. Simulation would be influenced by the alteration of dam and foundation conditions in the past seismic shaking, as well as by other changes with the passage of time.

In hindsight, any combination of input data might be adjusted until the computed and true behaviors are similar. Usefulness of the derived model would have to be proven.

Slope conditions

Nonuniform and varying conditions may weigh heavily in analysis of earth and rock slopes. Material properties may change because of deterioration, cracking, clogging, solution, or cementation. Throughout the years of operation, cyclic variations in reservoir loading can cause softening of embankment zones. Conditions such as soil fabric, interbedding, and segregation are not readily quantified. Numbers may not be assignable to some foundation irregularities.

The shape and character of the site can have major influence on the load-carrying capability of the dam. This applies to the geologic features and the inevitable changes in foundation rock and soils that affect resistance to movement or deterioration. Restraint may be conducive to arching of the fill in a narrow canyon or a deep foundation trench. Consideration also must be given to problems where the embankment abuts structures or conduits, including leakage through structural joints and cracks. Stirring all these ingredients into a mathematical mix should not be expected to produce more than a rough estimate of real performance.

Structural capability of concrete dams

Determining the structural capability of concrete dams has been facilitated by improved finite-element procedures that enable replication of structural faces and foundation anomalies. The quality of the simulation will depend on the extent to which local conditions are known. Foundation rock may include bedding planes, joints, shear zones, faults, clay seams, and solution channels. The orientations, gaps, and interface materials of these features could be vital determinants of resistance to shearing and compressive forces, as well as their function as hydraulic conduits or aquicludes (water barriers). Shear strength of potential sliding surfaces may be reduced by stress relief and weathering. The most vulnerable zones may be along such altered features that extend continuously through the dam site.

The upstream slope of Lower San Fernando Dam, an old hydraulic fill dam, slid out in the 1971 San Fernando earthquake as a result of embankment liquefaction. Although not associated with this event, the sedimentary foundation at the site had a long history of solution, caving, and erosion, requiring remediation by cement grouting.

Cracks in concrete dams are likely to originate at points of concentrated stress, as at changes in abutment slope. If the rock at the site is compressible, differential foundation deformations and consequent cracking may occur at concrete monoliths of different height. Arch dams are sensitive to abutment displacement on adversely oriented or weak rock planes. They may accommodate uniform site settlement but have little tolerance for shifts in the supporting rock. Configuration and properties of their foundation contacts are very important.

Slender members of some flat-slab (Ambursen) and multiple-arch dams built in the first half of the twentieth century may need careful analysis because of their susceptibility to deterioration in severe climates and their sometimes marginal resistance to lateral seismic loading. Advanced analytical practices are useful in evaluating measures taken to strengthen these dams, including rock bolting; post-tensioning; supplemental layers of concrete, shotcrete, or gunite; injection of synthetic adhesive; and shear walls or struts or concrete filling between buttresses.

Estimating probabilities by means of statistical analysis

The nature and scope of risk related to dams may defy prediction, mainly because of the unknowns of the site, structure, and seismic and hydrologic environments. This uncertainty has been viewed as a justification for estimating probabilities by statistical analysis. This requires rational examination of information and weighing the possible effect of its deficiencies.

Reckoning of the extremes imposed by flood or earthquake may not be refined much by probabilistic study unless the database is strong. Statistical extrapolation is most appropriate if performed on an ample, unbiased, continuous, minimally scattered record of the same kind of events during which there were no significant changes in governing factors. The reliability of the projection into the future diminishes rapidly for extrapolations that are many times the period of recorded data.

Flood conditions

Statistical analysis will not provide reliable estimates of floods with return periods as long as hundreds of millennia, which has been assumed for the probable maximum flood. Historical records alone may not be adequate for extrapolating more than 1,000 years. Estimating of very rare events may be hampered by lack or poor quality of gaging. In some cases, the data can be supplemented by study of observed effects of ungaged floods, such as movements of boulders whose shapes and sizes can be correlated with calculated hydraulic velocity and depth thresholds at which dislodgement and transport will occur. Projections also can be enhanced by paleohydrological study in regions where evidence of prehistoric floods may be found.

The practical and broadly accepted alternative for estimating extreme flows is the hydrometeorological method. This method is based on maximization and transposition of large recorded storms from other watersheds to determine the probable maximum precipitation that might be possible in the drainage area being studied. Adjustments are made for differences in air moisture and other rain-producing parameters. New software provides improved definition of watershed characteristics and spatial and temporal rainfall patterns. Various techniques have been used for positioning the transposed storm on the subject basin. Regions must have similarities in environment and storm types that make this transposition appropriate.

Records of rare storms in other basins can increase the hydrologic database substantially. Historic dam losses due to undersized spillways (Canyon Lake in South Dakota, Johnstown in Pennsylvania, Machhu II in India, and many others) might have been prevented by using today’s transposition techniques.

Seismic risk

Estimates of potential ground motion are especially difficult for dams near seismic sources. The nature of shaking varies with the size of the earthquake. Extrapolation from a limited record of lower-magnitude events might not tell much about a future great earthquake. Yet, predictions often have been made in this way. Probability of exceedance of a given intensity or acceleration has been shown by isoseismal contours for various periods of return, usually thousands of years. Whether this practice is realistic at all will depend on the length, volume, and content of the historical record and on supportive evidence such as from tectonic strain measurement and paleoseismic interpretation.

Soil variation

Statistical analysis has been used in risk assessment of variable dam or foundation materials. A weakness of such study in some cases may be in the transfer of data from one site to another. Each dam has a combination of setting and structural characteristics not exactly like any other. The unique nature of each project demands strong focus on local conditions.

Sheffield Dam failed by liquefaction of loose silty sands of the embankment and its foundation in the 1925 Santa Barbara earthquake.

Proponents of probabilistic analysis of soil deposits are handicapped by the difficulty of quantifying actual spatial stochastic variation. In the usual investigation, sampling is not spaced closely enough to provide more than a crude approximation of variations in the entire soil body. A statistical model could be questioned if only limited averaging is possible. The applicability of an average used in analysis will depend on the parameter and its range and pattern of variation throughout the earth mass being studied.

For example, an average of shear strengths that vary moderately might be used appropriately in a slope stability analysis, but an average permeability might be misleading in a seepage analysis. Individual values that differ sharply may determine points of concentrated leakage. At one dam in the southern U.S. where a grouted cutoff was established in floodplain alluvium, unit grout takes in holes on a spacing of 3 feet varied radically across the treated section, differing as much as 30 times between adjacent holes.

Attempts have been made to probe the uncertainties of earth slopes by probabilistic study. This study considered variation of density and shear strength, as well as hydraulic conductivity, which governs seepage and pore-water pressures and therefore effective stress. A complete analysis would have to include anomalies and directional variations in properties (anisotropy) as well as stationary variability. These features pertinent to slope behavior may be so singular that they are not amenable to statistical processing. Probabilistic studies of this kind do not tell what the safety margin is, any more than can be learned by conventional deterministic analysis. They indicate only the possible range of behavior corresponding to an array of soil models with different assumed distributions of properties. Safety factors indicated by such hypothetical study could vary widely, with the true value in an indefinite place between the extremes.

Exit gradients

Statistical analysis of the influence of material and permeability variations has been used to estimate the exit gradient of seepage emerging from an embankment face or a natural slope. This is a critical determination in evaluating the potential for backward piping, which is a major cause of dam failure. In an approach that combines statistical and finite-element techniques, each mesh element has its own randomly distributed permeability, so that the flow net is irregular. Analysis with a range of permeability patterns enables estimation of maximum possible exit gradients. The presence of highly pervious but ill-defined strata would complicate any seepage study.

Liquefaction

Some probabilistic ideas born and nurtured in academia have earned a measure of acceptance by engineers responsible for dams, particularly where they are joined with well-tested deterministic methods. For instance, statistical procedures for estimating the probability of liquefaction have been drawn from simplified approaches for defining liquefaction thresholds based on correlations of observed behavior and corresponding measurements of shear wave velocities, standard penetration, or cone penetration. Many engineers still prefer the deterministic methods, without coupling with statistical analysis. However, assessment of probabilities can enhance understanding of comparative safety margins.

Rating and fixing deficiencies

Relative risk of the dams in a system in terms of economics and loss of life can be evaluated on a common system-wide statistical basis to set priorities for preventive or remedial action. Probabilistic calculation is helpful in weighing the merits of alternatives for corrective work.

Summary

Dam analysis requires recognition of environmental characteristics that preclude accurate numerical conclusions. The reliability of calculations will depend on the quality of the database, most importantly the extent of knowledge of site conditions and of the extreme forces that might be imposed. Evaluation of a dam's capability must be focused on reducing the unknowns so that the analytical model is as representative of the actual project as possible. The limitations of methods, including mathematical modeling and probabilistic analysis, must be acknowledged. They are worth only as much as their factual input.

Mr. Jansen may be reached at 509 Briar Road, Bellingham, WA 98225; (1) 360-647-0983.

Bob Jansen, consulting civil engineer, was chairman of USCOLD (now the U.S. Society on Dams) and director of design and construction for the U.S. Department of the Interior's Bureau of Reclamation and the California Department of Water Resources. He was chief of the California Division of Dam Safety and directed investigations of the Baldwin Hills and Teton dam failures.

(Hydro Review, Vol. 27, Issue 5, September 2008, http://www.hydroworld.com/articles/hr/print/volume-27/issue-5/feature-articles/safe-dams-are-based-on-strong-data.html)

A New Approach to Identifying Risk, Prioritizing Dam Safety Work

Marc Smith, Claude Marche, and Benoît Robert

Social MediaTools

Canadian utility Hydro-Québec offers a new approach for identifying the factors that most contribute to overall risk, and using the results to prioritize dam safety work.

It is impossible to predict risk with certainty because two of the main characteristics of risk are complexity and uncertainty.[1] Even if a dam is judged to be safe, residual risk exists when people or property are in the flood zone. Dam failures, although not common, have serious consequences to people, property, and the environment. Therefore, establishing measures for reducing risk is an important responsibility of a dam owner.

Risk analysis involves breaking a complex system down into its fundamental components, then determining potential failure mechanisms and the physical processes that could cause each mechanism. Risk analysis methodologies commonly applied to dams include use of event trees and fault trees. An event tree is a visual representation of all the events that can occur in a system; a fault tree is a graphical tool that shows the relations between the various elements of a system to compute the reliability of that system. Use of either method allows the detailed analysis of potential failure mechanisms and provides qualitative insight as to how a series of events leading to dam failure might unfold. They also can be used quantitatively, with the help of probabilities, to assess the reliability of the system.

However, these methodologies present shortcomings related to representing dam risk in absolute terms. First, it is difficult to determine the safety of a dam according to rigid standards requiring a strictly binary ("safe" or "unsafe") outcome based on an absolute value of risk.[2] Second, use of these trees does not allow the determination of the most critical component of the series of events that could potentially lead to dam failure. Third, it is difficult to model, using these methods, the potential positive effects of rehabilitation measures on risk. Fourth, these methods do not take into account interactions between the various failure mechanisms. Although assumed to be independent, such mechanisms typically are strongly interrelated. For example, one initiating factor can trigger several failure mechanisms, and the occurrence of one mechanism can promote other mechanisms.

The interactions between failure mechanisms must be considered to accurately assess the overall risk of the dam system. Also, a more global approach is required to identify the factors contributing most to overall risk and to justify rehabilitation measures according to their potential to reduce risk.

One way to overcome some weaknesses in existing tools and capitalize on their merits is to use a Bayesian network. A Bayesian network is a graphical and mathematical tool showing the cause-and-effect relationships between the components of a system. To illustrate the use of Bayesian networks for dam safety analysis, we tested their application for analysis of the geotechnical and hydrological risks related to an embankment dam in Asia. We also used these networks to determine the risk related to reliability of the electrical/ mechanical components of the spillway at this dam. The results allowed selection of the rehabilitation method that presented the greatest improvement to dam safety with the lowest cost.

Understanding interactions between failure mechanisms

To demonstrate the interactions between failure mechanisms, consider an example where risk is represented by the probability of failure of an embankment dam. The example will be analyzed using event trees, then Bayesian networks.

Event tree

A strong earthquake can cause differential settlement and cracking in an embankment dam, possibly leading to internal erosion and catastrophic failure.[3] Such an earthquake also can trigger slides, followed by a loss of freeboard and failure due to overtopping. The event trees in Figure 1 show these two failure mechanisms. The probability of failure for either mechanism is the product of the conditional probabilities of all the individual events associated with that mechanism. The total probability of failure for this dam is equal to the sum of the probability of failure of the two mechanisms.

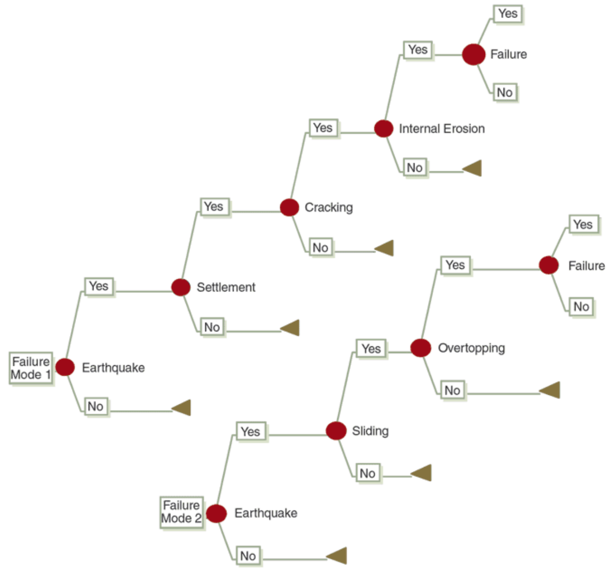


Figure 1: These generic event trees represent the risk to an embankment dam based on two failure mechanisms: settlement and sliding caused by a strong earthquake.

However, analysis of the overall risk to the dam must take into account the interactions between these failure mechanisms. For example, settlement can increase the risk of overtopping, and cracks resulting from settlement can lower the stability of the dam. In addition, a higher reservoir level contributes to the overtopping risk and influences both the potential of sliding and internal erosion by increasing pore pressures in the embankment. The reservoir level is controlled by the inflow and spillway operation. A strong earthquake also can affect the reliability of the spillway.

Therefore, a single initiator (an earthquake) can trigger different failure mechanisms (settlement and sliding), and realization of one failure mechanism (settlement leading to cracking, followed by internal erosion) can promote another (sliding followed by overtopping). These interrelations can be referred to as common-cause or common-mode effects, where a shared condition affects different failure mechanisms or when one mechanism affects another.

The total probability of failure for a dam also can serve as the basis for comparing the acceptability of the overall risk and the effectiveness of risk-reduction measures. However, the probabilities related to each failure mechanism need to be combined by taking into account that they are not mutually exclusive and therefore not simply additive. Common-cause or common-mode effects among multiple failure modes may be more the rule than the exception in dam safety.[4] These interrelations are difficult to describe using event trees because the different failure mechanisms are assumed to proceed independently using this mechanism, starting from an initial event. Also, as the number of events increases, the number of branches can grow to a point where the event tree becomes an inefficient way to represent overall risk.

Dam safety problems do not always fall neatly into customary loading categories. It is easy to overlook the interactive influences between the failure mechanisms.[2] The cause-and-effect relationships defining these mechanisms also are strongly related.

Bayesian network

Bayesian networks can be used to analyze dam risk in a global manner by describing the interrelationships between failure mechanisms. The use of Bayesian networks will help answer the following questions:

- What are the most significant factors contributing to overall risk?
- How should rehabilitation work be prioritized?

For a Bayesian network, the components of a system are determined using cause-and-effect logic and are represented by variables that form nodes. The dependencies between each node are represented by arrows going from cause to effect. Such a series of nodes and arrows describing a system forms a causal model. The strength of these dependencies is quantified by conditional probability tables that underly the causal model. These tables include the probabilities of occurrence of effects, given their causes. The causal model and the associated probabilities constitute a Bayesian network.

Figure 2 shows a Bayesian network indicating the probability of failure of a generic embankment dam. For clarify, only the causal model is shown. The individual events of the event trees in Figure 1 are represented in this network. However, the interactions between the failure mechanisms are now taken into account. Moreover, important variables in terms of risk of overtopping and internal erosion – namely reservoir level, inflow, and spillway operation – are included. The probability of occurrence of failure in Figure 2 combines the probabilities of the two failure modes (settlement and sliding) and considers the effects of the interacting failure mechanisms.

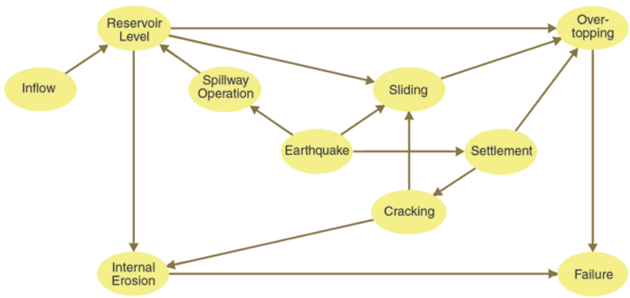


Figure 2: This Bayesian network represents the interrelationships between various failure mechanisms of an embankment dam. For example, internal erosion is affected by both reservoir level and cracking of the dam.

Each variable in the Bayesian network is defined by states that can include numerical values (reservoir level less than 100 meters, 100 to 110 meters, and greater than 110 meters) or literal descriptors (such as "yes" and "no" for internal erosion and "deep" and "surface" for cracking). These states are part of the conditional probability tables that underly the causal model.

For each variable, there is a conditional probability table that contains a conditional probability for every state of that variable given every combination of states of its causes. These probabilities are determined using data analysis, models of the phenomenon, and input from experts.[5]

One main function of Bayesian networks is the realization of inferences, which is the updating of conditional probabilities for some variables given new information about other variables. For example, the effect on the probability of failure of new evidence, such as the observation of deep cracking, is propagated numerically in the network using software – Hugin from Hugin Expert A.S. in Denmark – and algorithms based on Bayes' theorem, which may be considered the mathematical expression of learning by experience.[6] This approach is used to draw conclusions from observations. In the context of dam safety, these observations can result from changes in the behavior of a dam or from implementation of risk-reduction measures. In the latter example, the observation of deep cracking will increase the probability of failure of the dam.

Diagnoses provided through the use of Bayes' theorem include: determination of the most likely cause of a potential dam failure and identification of the most significant component of overall risk. A generic example of a diagnosis would be determining, between overtopping and internal erosion, the most likely cause of failure. This can be done by comparing the conditional probabilities calculated. For example, in determining the effect of sliding on the probability of failure, the Bayesian network in Figure 2 takes into account the interactions between all the failure mechanisms.

With this method, the probability of failure can be used as a common denominator for comparing the relative effectiveness of risk-reduction measures.[7] For example, possible risk-reduction measures could include constructing a filtering berm or upgrading a spillway. The effect of the first measure would be to cancel the risk of internal erosion. The effect of the second measure would be to keep the spillway operational after an earthquake. Prioritization is then realized by assessing the effects of these measures on the probability of failure by comparing the probability of failure without internal erosion and the probability of failure with the spillway operational.

Application of the method

We used a Bayesian network to solve a risk analysis problem for a dam in Asia that impounds water for irrigation and provides flood protection. The dam and spillway were of questionable integrity and were in urgent need of repair.

The 25-meter-high, 860-meter-long clay embankment dam does not have internal drainage and was founded on untreated soil. Construction occurred sporadically over ten years, based on the material and human resources available. Fill was placed without the use of heavy machinery or quality control procedures. The spillway, near the left abutment of the dam, is equipped with three gates that are lifted manually using a winch on a mobile gantry crane. An electrical motor is available to facilitate gate lifting.

A dam-safety assessment showed that internal erosion had initiated and was progressing due to the absence of filters in the dam and foundation. The dam owner lowered the reservoir level to slow the progression of internal erosion. However, this greatly reduced the water available for irrigation, negatively affecting the local farmers and economy. Repairs were needed so the reservoir level could be returned to its full capacity.

Insufficient spillway capacity and a lack of adequate freeboard represent a significant overtopping risk for the dam during typhoons because of the heavy precipitation and waves caused by strong winds. Moreover, the mechanical/electrical components of the spillway are unreliable. Also, the gantry crane becomes unstable during strong winds and cannot be operated.

Rehab work was needed to increase the safety of the civil works and to reduce the risks to the population living downstream. Such measures also would restore irrigation and flood-control capabilities. Four options were considered:

- Rehabilitate the existing gates and lifting mechanism;
- Add a fourth gate to increase spilling capacity;
- Construct a filtering berm to control ongoing internal erosion; and
- Build a parapet wall on the dam crest to increase storage volume and flood routing capabilities.

These measures could not be implemented quickly because of economical constraints, so it was essential to prioritize the options. Considering the importance of this rehab project for the local population and the numerous interrelations between the failure mechanisms, an assessment of the overall risk was required. This would make it possible to select the option offering the maximum risk-reduction potential at the lowest cost.

Development of a Bayesian network for this dam requires three steps. First, a global causal model is constructed to establish the cause-and-effect relationships between the failure mechanisms and the main variables defining the risk in terms of probability of failure. Second, some variables of this global model are divided into more specific components for a detailed analysis. Third, probability values are assessed to express the strength and degree of uncertainty of the relationships in the causal model.

The resulting Bayesian network is used to identify the most critical variables related to the probability of failure. It is used to prioritize rehabilitation options in terms of their potential positive effects on the probability of failure.

Causal model

Failure of this dam was analyzed by considering internal erosion and overtopping (see Figure 3). These failure mechanisms are affected by the reservoir level, which depends on precipitation and spillway operation. Wind speed affects both spillway operation and the risk of overtopping.

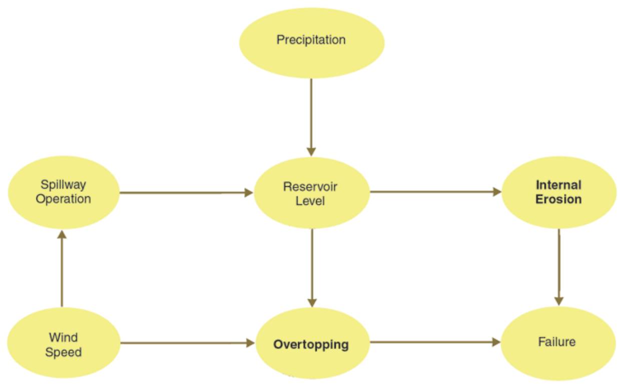


Figure 3: A global causal model is the first step in completing a Bayesian network for analyzing dam safety. This model shows how the two primary failure mechanisms (internal erosion and overtopping) are affected by other variables (such as reservoir level).

Some variables in the global causal model in Figure 3 (spillway gates lifting, overtopping, and internal erosion) were divided into more specific components for a detailed analysis. Figure 4 shows the results, which form the Bayesian network for this dam.

In general, the spillway is operational if the gates and lifting mechanism are functioning. The latter depends on the gantry crane and the electrical or manual winches. The three gates were considered separately to model partial opening of the spillway. The gantry crane also is affected by wind speed.

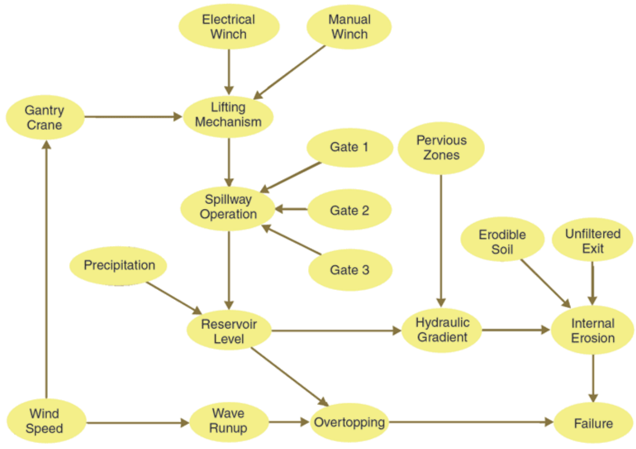


Figure 4: This Bayesian network, developed using the global causal model in Figure 3 on page 48, shows all the variables affecting failure modes for a clay embankment dam in Asia. This model shows the interactions between variables and the inputs that affect these variables.

Overtopping depends on both wave run-up caused by strong winds and reservoir level. The latter depends on spillway operation and precipitation.

Internal erosion requires carried soil particles to originate from the dam or its foundation, which can occur in the presence of an unfiltered exit, erodible soil, and a sufficiently high hydraulic gradient. The latter depends on the reservoir level and the presence of pervious zones.

Probabilities

Each variable in Figure 4 on page 50 is related to a conditional probability table that expresses the strength and degree of uncertainty of the causal dependencies pertaining to this variable. The conditional probability values were determined by a risk analysis team that included personnel familiar with the site. The evaluations were based on data, knowledge, and models that could be applied to the problem at hand. The assessment process is summarized in the following paragraphs.

The probability values for the lifting mechanism were determined using a fault tree. The lifting mechanism is always functional if the gantry crane is functional and the electrical or manual winch is functional. These logical relations are included in the Bayesian network so as to consider the reliability of the mechanical/electrical components of the spillway in a more global manner that includes the other failure mechanisms and the effect of wind speed on the gantry crane.

Other approaches also were used to determine conditional probability values. When large data sets were available, the probabilities were computed using statistics. This option was used for meteorological data, which helped determine probabilities related to wind speed and precipitation. Mathematical models – such as hydrological and flood routing calculations – were used to determine reservoir level for various return periods of interest. In this study, these models took into account precipitation and the number of gates in operation (zero to three).

Other probabilities, such as those related to internal erosion, were determined using expert judgement based on geotechnical models (such as seepage analyses) and knowledge of the specific characteristics of the dam and its behavior, derived from site inspections.

Risk reduction measures identified

Using the causal model shown in Figure 4 on page 50 and the underlying probabilities, a Bayesian network can be developed to identify the variable contributing the most to overall risk. Here, the probability of failure represents the overall risk and the decision basis for selecting the optimal risk-reduction measure. The probability of failure serves as the common denominator with which the negative effect of the observation or non-observation of one or more variables is calculated.

A variable with the most negative effect on the probability of failure is not necessarily the most critical. The probability of occurrence of that variable also should be considered. The variables contributing most to overall risk are those with both a greater negative effect and greater probability of occurrence. These parameters define the criticality of a variable or group of variables by multiplying the negative effect by the probability of the variable.

Inferences and calculations were made for every variable in Figure 4 on page 50 using specialized software. These calculations indicate that overtopping would be the most probable failure mechanism. The most critical variable related to overtopping is the gantry crane, which is affected by strong winds and the low reliability of its components. A functional failure of the gantry crane causes a non-operational spillway, which greatly increases the overtopping risk. Therefore, rehabilitation of the gantry crane would be the most efficient risk-reduction measure.

Prioritizing dam safety work needed

The main objective of structural rehabilitation work is to decrease the probability of failure. The most efficient options are directed to critical variables, to maximize the potential positive effect.

However, rehabilitation measures always carry a cost. In most circumstances, a dam owner would optimize its investment by prioritizing the measures and determining the option offering a combination of the highest risk-reduction potential for the lowest cost. The priority index is calculated by dividing the potential positive effect of the rehabilitation option by its projected cost.

Rehabilitation of the gates and lifting mechanism (option 1) includes the mechanical/electrical components as well as the gantry crane. In this case, all the equipment needs to be replaced because of the low reliability of every component. As a first approximation, the effect of this intervention would be a fully operational spillway. The probability of failure with the spillway being fully operational is then compared to the overall probability of failure to compute the positive effect. This process is repeated for the three other options.

Increasing spillway capacity (option 2) involves adding a gate and includes rehabilitation of the existing spillway. This would significantly decrease the risk of overtopping.

Construction of a filtering berm on the downstream toe of the dam (option 3) provides filtration to every seepage exit, decreasing the risk of an unfiltered exit.

Construction of a parapet wall (option 4) reduces the risk of overtopping but could temporarily increase reservoir level during flood events, thus negatively affecting the internal erosion risk. The net effect of this option on overall risk can be taken into account by modifying the Bayesian network shown in Figure 4 by adding a variable for the parapet wall.

The analysis indicated that construction of a filtering berm (option 3) would reduce the probability of failure by 35 percent, at a cost of about $1 million. Rehabilitation of the existing spillway (option 1) would reduce the probability of failure by 45 percent but would cost about $1.7 million. The priority index is higher for option 3 than for options 1. Options 2 and 4 had much lower priority index values. Therefore, the optimal risk-reduction measure in technical and monetary terms is construction of a filtering berm.

This analysis covers the technical side of the problem, but there also are social, environmental, and legal aspects. For example, construction of a filtering berm may be the optimal risk-reduction measure, but local legislation could specify a minimum spilling capacity. Therefore, a spillway upgrade could be compulsory.

In addition, some rehab measures can have negative outcomes. Increased spilling capacity would provide more safety for the structure but could endanger the downstream population when the spillway operates during a large flood. In this case, the probability of failure and consequences given a failure or large outflows must be considered jointly.

Mr. Smith may be reached at Hydro-Québec, 75 Rene-Levesque, Montreal, Québec H2Z 1A4 Canada; (1) 514-289-2211, extension 5162; E-mail: smith. marc@hydro.qc.ca. Messrs. Marche and Robert may be reached at Ecole Polytechnique de Montreal, CP 6079, Succ. Centre-ville, Montreal, Québec H3C 3A7 Canada; (1) 514-340-4711, extension 4801 (Marche) or 4226 (Robert); E-mail: claude.marche@polymtl.ca or benoit.robert@polymtl.ca.

Notes

1. Denis, H., Comprendre et Gérer les Risques Sociotechnologiques Majeurs, éditions de l'école Polytechnique de Montréal, Montréal, Québec, Canada, 1998.

2. Vick, S.G., "Engineering Application of Dam Safety Risk Analysis," Proceedings of the 20th International Congress on Large Dams, International Commission on Large Dams, Paris, France, 2000, pages 325-335.

3. Pells, S., and R. Fell, "Damage and Cracking of Embankment Dams by Earthquake and the Implications for Internal Erosion and Piping," Proceedings of the 21st International Congress on Large Dams, International Commission on Large Dams, Paris, France, 2003, pages 259-274.

4. Vick, S.G., Degrees of Belief, ASCE Press, Reston, Va., 2002.

5. Hartford, D.N.D., and G.B. Baecher, Risk and Uncertainty in Dam Safety, Thomas Telford, London, 2004.

6. Hacking, I., Probability and Inductive Logic, Cambridge University Press, Cambridge, Mass., 2001.

7. Smith, Marc, "Réduction du Risque Barrage par l'utilisation des Réseaux Bayésiens," PhD thesis, école Polytechnique de Montréal, Montreal, Québec, Canada, 2005.

Marc Smith is an engineer with Hydro-Québec. Claude Marche and Benoît Robert are professors at École Polytechnique de Montréal. The authors developed the new approach detailed in this article as part of a research project on dam safety risk analysis.

µ Peer Reviewed

This article has been evaluated and edited in accordance with reviews conducted by two or more professionals who have relevant expertise. These peer reviewers judge manuscripts for technical accuracy, usefulness, and overall importance within the hydroelectric industry.

(Hydro Review, Vol. 27, Issue 6, October 2008, http://www.hydroworld.com/articles/hr/print/volume-27/issue-6/technical-articles/a-new-approach-to-identifying-risk-prioritizing-dam-safety-work.html)

ΦΡΑΓΜΑΤΑ ΑΠΟ ΣΚΛΗΡΑ ΕΠΙΧΩΜΑΤΑ ΚΑΙ ΚΥΛΙΝΔΡΟΥΜΕΝΟ ΣΚΥΡΟΔΕΜΑ

Hickory Log Creek: Building a Roller-Compacted-Concrete Dam

James M. Parsons, Randall P. Bass, Charles M. Kahler, and Rodolfo T. Ruiz-Gaekel

Social MediaTools

To overcome site constraints and to meet a tight timeline for completing its new Hickory Log Creek Dam, the Cobb County-Marietta Water Authority and the city of Canton, Ga., chose to build a roller-compacted-concrete structure. Construction of the dam, completed in November 2007, taught several valuable lessons about the use of RCC.

Construction of Hickory Log Creek Dam on Hickory Log Creek, a tributary of the Etowah River in Georgia, was completed in November 2007. Hickory Log Creek Dam is the highest roller-compacted-concrete (RCC) dam in Georgia and the fourth highest in North America. The dam is 180 feet high and 956 feet long. The need for this dam was initially identified in a 1996 study, to increase water available for the growing area northeast of Atlanta.

Before the dam could be built, Cobb County-Marietta Water Authority and the city of Canton, Ga., needed to determine whether to build an earthfill or RCC dam. Site restrictions, costs, and schedule led to the selection of an RCC dam. This option would save about $4 million and one construction season compared with building an earthfill dam.

Impoundment of the reservoir behind Hickory Log Creek Dam began in November 2007. When this process is completed in one to two years, the reservoir will provide 44 million gallons of water a day for the city of Canton and the wholesale customers of the water authority. Lessons learned from the construction of this dam could help others who are designing and building RCC dams.

Why the dam was needed

Significant population growth in the northeast area of Atlanta resulted in growing demand for water in the region. To meet this demand, the Cobb County-Marietta Water Authority and the city of Canton started the planning process for a new water supply reservoir.

The site chosen for the proposed Hickory Log Creek Dam is near an 8.5-acre lake on Hickory Log Creek that was part of the Canton Mills Lake manufacturing plant along the Etowah River. The Canton Mills heirs donated 300 acres in the area where the Hickory Log Creek Reservoir would be located.

The reservoir needed to yield 44 million gallons of water per day. Using this yield, the dam developers established the final dam site and the normal pool elevation. Inflows into the resulting 411-acre Hickory Log Creek Reservoir are supplemented by a pumping station located about 7,000 feet below the dam on the Etowah River. This station pumps water from the Etowah River when inflow from Hickory Log Creek is insufficient to fill the reservoir. Once the reservoir is filled initially, the pump station will only be used to replenish the water in the reservoir that is released during drought conditions.

Choosing the type of dam to build

Early planning studies by Schnabel Engineering, including

subsurface exploration performed in November and December 2004, indicated that both earthfill and RCC dams were viable options for the site. Because the type of dam built would not affect the yield of water, the selection would be based on cost and schedule.

In September 2004, the dam owners chose a design team consisting of Brown and Caldwell and Schnabel. Schnabel's tasks included performing an alternative analysis to recommend the appropriate dam type and to design the selected dam. Design tasks performed by Brown and Caldwell included designing the pump station and the associated 42-inch-diameter pipeline.

The key parameters considered during the alternative analysis were associated with: spillway type and size, material availability, schedule, and project cost.

Due to property constraints, the difference between the normal pool and flood pool elevations was only 10 feet. This required construction of a large spillway to pass the probable maximum flood (PMF). The size of the spillway was an important factor in selecting an appropriate dam type.

The design storm used for the project was the probable maximum precipitation (PMP). Over the 8.2-square-mile drainage basin, this produced an inflow of nearly 64,000 cubic feet per second (cfs) during a hypothetical six-hour storm.

The earthfill dam option considered contained a 170-foot-high inlet/outlet tower with a large-diameter pipe through the base of the dam. This tower would serve as the principal spillway, passing all flows up to the 100-year event. An earthen emergency spillway would be located off the right abutment. This spillway would require a crest width of 600 feet. More than 25 acres of additional land would have to be acquired to accommodate the emergency spillway. For the RCC option, no emergency spillway would be required that was separate from the dam.

For both dam types, material availability was a concern. Most of the site consisted of weathered mica schist. The ridge tops had partially weathered rock just below the ground surface. This material broke down to lightweight micaeous sandy silt.

A concrete cutoff wall was built at both ends of the abutments of Hickory Log Creek Dam to provide seepage control.

For an earthfill dam, no suitable core material was located within the limits of the dam or reservoir. As a result, the more than 200,000 cubic yards of core material would have to come from off site. In addition, about 1.2 million cubic yards of shell material would have to be collected from within the reservoir area, with care taken to prevent the creation of unstable slopes in the reservoir. This would mean that haul distances would exceed 4 miles, and some land above normal pool would have to be purchased to acquire all the fill material.

With regard to the aggregate needed to build an RCC dam, the hot construction market in the Atlanta area created a shortage of No. 57 stone. Consequently, the design team decided to base the RCC mix proportion plan on using a graded aggregate base material, supplemented with 15 to 20 percent of No. 4 stone. Historically, projects that used a single aggregate stockpile experienced problems with segregation. In addition, if cooling of the RCC was required, the options were limited when the fine and coarse aggregate were combined.

Another concern was the project schedule. The city of Canton had an ambitious goal of completing the project by the fall of 2007. It would have been difficult to construct a 180-foot high earthfill dam on this schedule, due to the normal yearly rainfall of more than 52 inches. Placement of large quantities of earthfill during the wet winter months typically would have been impossible.

However, designers determined an RCC dam could meet that schedule, if the project could be separated into two construction phases. Separating the project into two phases would result in filling of the reservoir at least six months earlier than single-phased dam construction.

The Phase I contract for Hickory Log Creek Dam would consist of foundation excavation and treatment; infrastructure improvements such as construction of roads, bridges, and staging areas; and erosion and sediment controls.

The Phase II design work, consisting of the dam and ancillary facilities, would take place while the Phase I construction was under way. The design and construction schedule had RCC placement occurring between January and May 2007. This timeline would avoid the additional cost associated with forced cooling of the RCC, which would be required if RCC was placed in warmer months.

Finally, cost was an issue. Overall, Schnabel determined that the RCC option would cost about $4 million less than the earthfill option. The higher cost for the earthfill dam was due primarily to the cost of acquiring additional land and at least another six months of construction time.

Developing a design for the RCC dam

Work on the design for Hickory Log Creek Dam began in late 2004. To obtain more detailed subsurface information, such as rock strength parameters, the developers hired QORE Property Sciences of Atlanta to perform a second subsurface exploration in the first quarter of 2005. The results confirmed that the conditions assumed during the alternatives analysis were true and allowed determination of the foundation excavation limits.

In late 2004, the 8.2-square-mile drainage basin was predominantly wooded. However, real estate trends in the metro Atlanta area at the time indicated likely heavy commercial and residential development in this basin over the next 20 to 30 years. Georgia Safe Dams Program guidelines require that any new construction or rehabilitation of dams in the state requires evaluation of future land use during the hydrology and hydraulic study. Schnabel performed this study during the same time frame as the alternative analysis.

Estimated PMP for this drainage basin is 30.3 inches during a hypothetical six-hour storm event. Based on this information, estimated inflow into the reservoir is nearly 64,000 cfs. With a maximum dam freeboard of 10 feet, designers determined a 250-foot-wide spillway crest was required to safely pass the design storm. Schnabel designed a 110-foot-long gated spillway section, centered within the 250-foot spillway width. The 250-foot-wide spillway section has two bridge piers located on either end of the gated spillway section. The 110-foot-long gated spillway section consists of a 6-foot-high crest gate from Obermeyer. When this gate is fully lowered, this spillway section can pass 16 feet of reservoir head.

Different sized dozers were used to spread the roller-compacted concrete for Hickory Log Creek Dam. The equipment featured a laser-guided system to obtain a level surface.

The dam site contained a very narrow valley with steep abutments. The floodplain limited the width of the stilling basin to only 130 feet. This resulted in the 250-foot-long spillway crest transitioning to a 130-foot-wide stilling basin. The design team performed a literature search to identify hydraulic model studies performed on converging spillways that would match the design configuration for Hickory Log Creek Dam. The search identified model studies performed on converging spillways up to 15 degrees, but this spillway would have a converging angle of 25 degrees. The designers contracted the Utah Water Research Laboratory at Utah State University in Logan to perform a physical model study of the proposed spillway system.

The empirical design from Schnabel indicated the length of the stilling basin should be 130 feet. However, velocities in the stilling basin measured during the physical model study indicated the stilling basin could be shortened to 80 feet. This is reflected in the final design. Results from the physical model study also indicated that the 250-foot-long spillway and 130-foot-wide stilling basin could safely pass the design storm.

The intake system designed for the dam consists of a 72-inch-diameter horizontal steel pipe at the base of the dam. Near the front face of the dam, a 42-inch-diameter steel tee protrudes vertically from the larger pipe. Three reservoir intakes at different elevations attach to the vertical pipe.

The dam design also incorporated a seepage control and collection system. The first line of the seepage control system was a double row grout curtain. The grout curtain was constructed using a real-time monitoring system to evaluate changes in the foundation and to make rapid engineering decisions regarding grout mix design, the need for secondary holes, and down-hole grout pressures.

A drainage gallery with foundation drains was designed to reduce uplift pressure on the base of the dam. The foundation drains range from 25 to 30 feet deep on 20-foot centers. The center of the drainage gallery is 18 feet downstream of the dam baseline, and the gallery extends up about two-thirds of the height of the dam on both abutment faces. The seepage collection system beneath the portion of the dam founded on partially weathered rock consists of a sand and gravel trench drain discharging to the drainage gallery. All of the flows collected in the drainage gallery discharge into the stilling basin.

The dam designers specified the characteristics of the RCC to be used to build Hickory Log Creek Dam. The RCC would have a 180-day compressive strength of 2,000 pounds per square inch (psi). The RCC mix design program incorporated a total cementitious quantity of 300 pounds per cubic yard (pcy) of cement and flyash. Because of the limited time from completion of the design to the beginning of construction, a conservative RCC lift maturity of 500 degree-hours was used to define a lift cold joint for this project.

In addition to undergoing review by a Schnabel internal review panel, the design work was reviewed at significant milestones by the Georgia Safe Dams Program. The design team used design review workshops to keep all stakeholders informed of the design progress and results. The state was very involved because this was the highest dam it had permitted since the program's inception in 1978.

The construction documents contained two types of RCC cold joints. The first cold joint was declared when the ambient air temperature exceeded 500 degree-hours. At this point, the entire RCC surface had to be covered with a bedding mix just before placing the next lift of RCC. The second type of cold joint was declared when 36 hours elapsed between RCC lift placements. When this second type of cold joint occurred, the entire lift had to be washed with high-pressure air/water jets and the entire RCC surface had to be bedded just before placing the next lift of RCC.

Waterproofing of the upstream face of the dam was achieved using synthetic geomembrane-lined prefabricated panels. This membrane system was selected because of the nature of the "soft" rock of the dam foundation. Some stress redistribution within the RCC mass could be expected, and a crack between monolith joints could not be ruled out. The membrane liner would prevent water from entering the body of the dam if a crack did develop.

Building the dam

Work was performed in two phases to shorten the timeline for completion.

Phase I

For this phase, bids from five contractors were received in September 2005, ranging from $5.1 million to more than $9 million. In October 2005, Thalle Construction Inc. was awarded the contract for the Phase I work, to be completed within 270 calendar days. The major tasks in the Phase I contract consisted of the foundation excavation, abutment blanket construction, temporary stream diversion, concrete cutoff wall construction, and grouting program.

Foundation excavation, which began in January 2006, included the removal of about 170,000 cubic yards of soil and rock. Some of the finer-grained soils removed adjacent to the floodplain area were spoiled in a controlled fashion against a large, exposed rock face upstream of the right abutment. This "soil blanket" serves to reduce seepage beneath the right abutment. Thalle completed the mass excavation by late February 2006 and began blasting within the rock foundation in early March 2006. Blasting operations were completed by July 2006.

Construction of a concrete cutoff wall was necessary at the very ends of the abutment sections, which were founded on partially weathered rock. The rock contained numerous seams of fine-grained material that would limit installation of a grout curtain in this area. Therefore, Thalle constructed a 20-foot-deep, 3-foot-wide concrete cutoff wall in these locations.

Prefabricated panels covered with a synthetic geomembrane liner were used to waterproof the upstream face of Hickory Log Creek Dam.

The grouting program was designed with the assistance of Dr. Donald Bruce with Geosystems L.P. The program consisted of a double row grout curtain with primary holes located at 20-foot centers. The depth of the grout curtain was generally 25 feet in the floodplain area where the freshest rock was observed. The grout curtain extended anywhere from 35 to 80 feet deep within the abutment areas. Subcontractor Nicholson Construction Company conducted the grouting, which began in late June 2006 and was finished by mid-October 2006.

The procedure for the grouting program involved: drilling of each grout hole, water pressure testing of each stage within the grout hole, and then grouting of each stage in the grout hole, if required. The water pressure testing results and grouting test results were monitored in real-time using Nicholson's Spice Program. Performing water pressure testing of each stage gave the contractor and engineer an opportunity to predict or anticipate whether or not the stage would take grout.

Phase II

With a low bid of $36.5 million, Thalle was awarded the Phase II contract in August 2007. ASI Constructors, a subcontractor to Thalle, mixed and placed the RCC; set the upstream precast panels; set the downstream step forms; placed the abutment contact concrete and spillway facing concrete; and welded the geomembrane liner.

RCC was produced using a Johnson-Ross portable batch type plant and a HyDam 4500D mixer from IHI Construction Machinery Limited. This batch plant was configured to sustain a production rate of 800 tons of RCC per hour. The batch plant and mixer were computer controlled using a computerized batching system from Command Alcon Corp.

RCC was delivered from the batch plant to the dam conveyor belts supplied by Rotec Industries. RCC was delivered to different locations of the dam using a conveyor tripper and a 60-foot-long swinging conveyor from Rotec. The conveyor system was supported using a pea gravel jack post system, which consisted of 12 jacking posts spaced about 100 feet apart along the length of the dam. Each post was filled with pea gravel, which served as foundation for the post once the conveyor was raised. The conveyor system was raised every other day, using a hydraulic jacking frame after the RCC was placed.

The downstream steps of Hickory Log Creek Dam were formed using grout-enriched roller-compacted concrete (RCC), which provides an improved appearance over typical exposed RCC.

Once delivered to the dam, the RCC mix was spread in 1-foot lifts using three different types of dozers, depending on the space circumstances. A small D21 dozer from Komatsu was used in areas around the gallery, on the upstream side where space was constrained. In the main section of the dam where space did not present problems, a large 850J dozer from John Deere was used to spread the RCC. This dozer had a special large blade that allowed the RCC top to be pushed without causing segregation. A mid-size D5 dozer from Caterpillar was used to help spread the RCC on the upstream and downstream sides of the lift. The D5 was also used to finish grade the RCC lift. All equipment used to spread the RCC was equipped with a laser-guided system to obtain a level surface.

Compaction of the RCC was achieved using double (DD-130) and single (SD-100) smooth steel drum rollers from Ingersoll Rand. To achieve the specified density, normally four passes with the double drum roller were required. The areas adjacent to the upstream and downstream sections of the dam were compacted using a smaller DD-24 double roller from Ingersoll Rand. Areas where access was difficult or restrained typically were compacted using plate tampers and jumping jacks made by different manufacturers.

Thalle used a Low Flow Pro C10 dry batch type concrete plant from Coneco Equipment to produce the structural concrete, mortar mix, and self-consolidating concrete used for the ancillary structures. The dry batch plant produced about 9,000 cubic yards (4,500 cubic meters) of conventional concrete and 1,500 cubic yards of bedding mortar. Self-consolidated concrete was produced from this plant as structural concrete for the spillway training walls.

RCC placement started in mid-December 2006 and was completed in early June 2007. Placement was typically done during the cool hours of the day during the winter, followed by a night shift placement. During late spring and early summer, RCC placement was performed during the night only.

Cold joints were cleaned by air blowing the surface using 375-CFM air compressors from Ingersoll Rand and small high-volume backpack blowers. The high-volume pressurized air was used to remove loose debris, rocks, and laitance on the surface. Air blowing was done when joint maturity was less than 500 degrees Fahrenheit (F)-hours.

Pressure washing the lift was performed using a 20203D-78 pressure washer from NLB Corporation. This procedure was done on a cold joint surface with more than 500 degrees F-hours, or a surface that did not receive RCC during 36 hours after the lift was compacted. Excess water on the surface was removed using two vacuum trucks. Continuous water curing of the surface was done after cleaning until the next RCC lift was started.

Foundation drains, piezometers, and inclinometers supplied by Geocomp were drilled and installed during the gallery construction. Instrumentation consisted of more than 50 thermistors, 18 piezometers, four inclinometers, and four observation wells. Several permanent surveying monuments will be installed inside the gallery and at top of the dam for continuous monitoring.

All concrete prefabricated panels used for the vertical upstream face and downstream chimney section were fabricated on-site. Thalle built five concrete casing beds to produce the different sizes of panels. A total of 2,000 full-size panels (6 feet by 16.5 feet) and 500 half-size/special size panels were fabricated.

The panels on the upstream face of the dam were waterproofed using a flexible CARPI 40 mil synthetic geomembrane from Carpi. Installation of the geomembrane was accomplished using the Winchester System, which involves embedding the material on the back of the prefabricated facing panels. Also, the upstream prefabricated panels served as formwork against which the RCC was placed. Prefabricated panels were aligned and installed such that the panel joints would not cross a contraction joint on the upstream face. The liner would extend across the contraction joints between the panels to prevent water from seeping along the contraction joints.

The panels on the downstream side of the chimney section do not have a waterproofing synthetic liner. A decorative stone face was used on the exposed downstream panels to assimilate the structure with its natural surroundings.

Wood forms were used to form the 3-foot-high downstream steps for both the overflow and non-overflow sections of the downstream side of the dam. Grout-enriched RCC was used to give the exposed downstream steps of the dam an improved appearance over typical exposed RCC. This was the first use of grout-enriched RCC on a dam in North America where the material is exposed.

A total of 218,000 cubic yards of RCC were placed in 117 days at Hickory Log Creek Dam. Reservoir filling began in November 2007 and should be completed within 18 months. Total cost of the project was $41.5 million.

Lessons learned

When determining construction costs, it is critical to pay close attention to market conditions when the quantity of materials is large. The day before bids were due on the Phase I contract, fuel prices doubled and there were reports of shortages for the near future. During the post-bid opening briefing with the bidders, it was determined that the bidders added $200,000 to $300,000 at the last minute to cover the fuel increase. For Phase II, the contract documents included a clause that removed the risk of a fuel spike from the contractor.

It is recommended that a set retarder be specified for the RCC mix to extend the initial set of the RCC, unless it is assured that ambient weather conditions will keep the RCC mix temperature at 50 degrees F or less. It is beneficial to try to reduce the occasions where a bedding/ bonding mix is required. Placing bedding mix requires dedicated labor, and too many times this labor is directed elsewhere on the project. Bedding mix tends to be placed too far out in front of the RCC, and it starts to dry out or vehicular traffic tracks through the bedding mix and create a mess on the lift surface.

Lastly, grout-enriched RCC was successfully used for the non-overflow downstream steps. A 1:1 grout mix was specified. It is recommended that a 0.8:1 (water to cement) ratio be specified to allow for a more cementitious paste at the surface. This would allow the surface to have a somewhat troweled appearance and minimize adverse slope that impounds water on the steps.

Mr. Parsons may be reached at Cobb County-Marietta Water Authority, 1660 Barnes Mill Road, Marietta, GA 30661; (1) 770-426-8788; E-mail: jparsons@ccmwa.org. Mr. Bass may be reached at Schnabel Engineering, 5975 Shiloh Road, Suite 114, Alpharetta, GA 30005; (1) 770-781-8008; E-mail: rbass@schnabel-eng.com. Mr. Kahler may be reached at Schnabel Engineering, 6445 Shiloh Road, Suite A, Alpharetta, GA 30005; (1) 770-781-8008; E-mail: ckahler@schnabel-eng.com. Mr. Ruiz may be reached at Paul C. Rizzo Associates, 4135 Browning Chase Drive, Tucker, GA 30084; (1) 678-358-3383; E-mail: rodolfo.ruiz@yahoo.com.

Jim Parsons, P.E., is director of engineering with Cobb County-Marietta Water Authority. Randy Bass, P.E., is senior associate and Chuck Kahler, P.E., is associate with Schnabel Engineering Inc. Bass was the overall project manager and Kahler was the lead designer and construction manager for Hickory Log Creek Dam. Rodolfo Ruiz-Gaekel, formerly senior staff engineer with Schnabel, is now project consultant with Paul C. Rizzo Associates Inc. He was the lead resident engineer for the dam construction.

Hydro Review, Vol. 27, Issue 1, March 2008, http://www.hydroworld.com/articles/hr/print/volume-27/issue-1/feature-articles/dam-construction/hickory-log-creek-building-a-roller-compacted-concrete-dam.html

Roller-Compacted-Concrete Dams: Design and Construction Trends

Fares Y. Abdo

Social MediaTools

A review of the design and construction of five recently completed roller-compacted-concrete dams in the U.S. reveals that many new design details and construction methods have been adapted to enhance the final product.

Roller-compacted concrete (RCC) continues to gain recognition as a competitive material for building new and rehabilitating existing dams. Over the past two decades, many design details and construction methods have been adapted to enhance the final product while maintaining the speed of construction that provides RCC its competitive edge.

More than 370 RCC gravity dams higher than 50 feet have been built worldwide using RCC, 43 of these in the U.S. Many more RCC gravity dams less than 50 feet high have been built worldwide.

The first two large RCC gravity dams in the U.S. – Willow Creek in Oregon and Upper Stillwater in Utah – were built in the 1980s. These dams experienced seepage through lift joints and at shrinkage cracks. Since that time, design engineers, owners, and contractors have been looking for innovative methods to improve durability and aesthetics of RCC and to limit seepage. Several facing systems are being used on dams built today, including air-entrained conventional concrete with crack inducers and water stops, precast concrete panels, and waterproofing membranes.

Five medium-sized RCC gravity dams were built in the U.S. between 2004 and 2008. A review of the main elements design engineers have to consider in regard to RCC provides important information on the latest design details, mixes, and construction methods.

Using RCC for U.S. dams

In the late 1970s, promising research results led the U.S. Army Corps of Engineers to change the design of Willow Creek Dam in Oregon to RCC. Originally, the Corps planned to build a rockfill embankment dam. About a month later, the U.S. Department of the Interior's Bureau of Reclamation adopted this new technology for its Upper Stillwater Dam in Utah.[1]

Thus, RCC emerged as a viable new type of dam. The first to be completed was Willow Creek Dam, in 1982. At this dam, 433,000 cubic yards of RCC were placed in less than five months, at an average cost of $19 per cubic yard. The dam had no transverse joints and used a lean (low cementitious content) dry RCC mixture with nominal maximum aggregate size of 2.5 inches. Precast concrete panels were used on the upstream face, and the downstream face was unformed. Although Willow Creek Dam was deemed structurally sound, excessive water seepage at lift joints occurred during first filling of the reservoir.

A few years later, Upper Stillwater Dam was built. Construction of the dam began in 1985 and was completed in 1987. At 294 feet high and with a crest length of 2,673 feet, the dam required 1,471,000 cubic yards of RCC. As of September 2008, the dam remains the largest volume RCC dam completed in the U.S. Reclamation's approach to building Upper Stillwater Dam was quite different from the Corps' approach to Willow Creek Dam. Reclamation elected to use a richer RCC mixture (higher cementitious content) with a wetter consistency. The upstream vertical face and downstream stepped face of the central spillway section were slipformed using conventional concrete. The richer RCC mix produced a higher tensile strength and thus reduced the cross-section of the dam. In addition, the richer mix and the upstream conventional concrete facing provided better seals and prevented seepage at lift joints.

Upper Stillwater Dam did not include contraction joints. Vertical thermal cracks developed at an average spacing of about 190 feet. The cracks were not structurally significant; however, one crack produced excessive water leakage and required waterproofing repairs.[2]

Much was learned from the RCC dams built in the 1980s. Although these dams were never in structural jeopardy, future designs placed more emphasis on seepage and crack control for most projects. Designers of dams built during and after the 1990s incorporated different types of facing systems and control joints. They typically used richer RCC mixtures, a smaller maximum aggregate size, stricter construction requirements, special lift joint treatments, upstream membranes, and special facing mixtures to improve watertightness and bonding at lift joints.

Five recent medium-sized RCC dam projects

For the purpose of this article, medium-sized RCC gravity dams are those higher than 50 feet with a concrete volume not exceeding 300,000 cubic yards. The five dams featured in this article were built between 2004 and 2008. The volume of RCC used ranged from 13,800 cubic yards to 218,000 cubic yards, and their heights vary from 70 to 188 feet (see Table 1). The dams are in Colorado, Georgia, Virginia, and West Virginia. In Georgia, deterioration from freeze-thaw cycles is of minimal concern. However, in the other three states, numerous freeze-thaw cycles take place annually. The main purpose of all five dams is to provide water supply for nearby communities.

Table 1: Design Features of Five Medium-Sized RCC Dams

Dam, Date of Completion	Height (in feet)	Length (in feet)	RCC Volume (in cubic yards)	Conventional Concrete Volume (in cubic yards)	Upstream Facing	Facing on Downstream Nonoverflow Section	Facing on Downstream Overflow Section
Elkwater Fork[1] 2008	128	670	132,000	8,700	Precast concrete panels with polyvinylchloride (PVC) membrane bonded to downstream face	Formed RCC steps	Conventional concrete steps
Genesee No. 2[1] 2007	103	360	50,000	3,000	Conventional concrete with water stops	Unformed RCC covered with earth and vegetation	Unformed RCC covered with earth and vegetation
Hickory Log Creek[1,2] 2008	188	956	218,000	9,000	Precast concrete panels with PVC membrane bonded to downstream face	Grout-enriched RCC steps	Conventional concrete steps
New Big Cherry 2005	85	370	13,800	7,000	Conventional concrete with water stops	Conventional concrete steps	Conventional concrete steps

Notes
[1]This dam has a grout curtain. [2]This is the only one of the five dams with a drainage and inspection gallery.

New Big Cherry Dam in Wise County, Va., replaced a 70-year-old cyclopean concrete dam that suffered from structural deficiencies and had a spillway capacity less than that needed to meet the state dam safety requirements. In addition to increasing the spillway capacity, the new dam is 7 feet higher than the old dam, which increased the reservoir water storage from 359 to 633 million gallons.

Pine Brook and Genesee No. 2 dams in Colorado have similar designs, with a conventional concrete upstream face and an unformed downstream face covered with soil and vegetated. Both construction sites were congested, with minimal space for RCC plants, aggregate stockpiles, and RCC handling equipment. Pine Brook was the first design-build dam in Colorado, whereas Genesee No. 2 was built based on a negotiated contract with the lowest bidder. Most of the RCC aggregates for the two dams were mined and processed on site.

Hickory Log Creek Dam in Canton, Ga., about 30 miles north of Atlanta, began impounding water in January 2008. It is the tallest non-federally-regulated concrete dam in the state. Once filled, the reservoir will supply much-needed water especially after the region endured one of the most severe droughts on record, in 2007. The developer used crushed concrete aggregates hauled to the site from a nearby rock quarry.

The downstream face of Pine Brook Dam in Colorado was made of unformed concrete that was covered with soil and vegetation. The dam has a conventional concrete upstream face.

Elkwater Fork Dam in Randolph County, W.Va., was built to supply water to Elkins, W.Va., and surrounding communities. The dam area is distinguished by its annual precipitation of about 60 inches, making it an ideal location for a water supply reservoir. RCC placement was completed in 2007, and the entire project is expected to be completed in late 2008. Again, the developer used crushed concrete aggregates hauled to the site from a nearby rock quarry.

Dam design features

Table 1 summarizes the design features of the five dams. Some designs are simpler than others, which affected material cost and speed of construction, and consequently the project cost. The following sections offer specifics of the individual designs with respect to: galleries and foundation drains, grout curtains, facing systems, RCC mixtures, lift joint treatment, and contraction joints.

Galleries and foundation drains

Only the tallest of the five dams, Hickory Log Creek, has a drainage and inspection gallery. The gallery is 18 feet downstream of the dam baseline and extends up the majority of the right and left abutments. The seepage collection system beneath a portion of the dam consists of sand and gravel trench drain discharging into the gallery. Flows from the gallery discharge into the stilling basin.

Table 2: RCC Mix Proportions for Five Medium-Sized RCC Dams

Dam	Portland Cement (in lb/y^3)[1]	Fly Ash (in lb/y^3)[1]	Aggregates (in lb/y^3)[1]	Free Water (in lb/y^3)[1]	Vebe Time (in seconds)	Specified Compressive Strength (in psi)[2]
Elkwater Fork Mix 1	100	150	3,720	–	15 to 25	1,500 at one year
Elkwater Fork Mix 2	125	185	3,660	–	15 to 25	2,500 at one year
Genesee No. 2	180	104	3,552	–	–	1,500 at 90 days
Hickory Log Creek	135	165	3,600	225	20 to 30	2,000 at 180 days
New Big Cherry	129	129	3,684	220	–	1,500 at 90 days

Notes
[1]Pounds per cubic yard. [2]Pounds per square inch.

At Elkwater Fork Dam, drilled foundation drain holes are angled from the downstream toe of the dam to relieve uplift pressure in the foundation.

For the three smaller dams, designers elected to eliminate drainage galleries and foundation drains.

New Big Cherry Dam was designed to minimize long-term operation and maintenance concerns. One of the design objectives was to eliminate the drainage gallery, dam drains, and foundation drains.[3] To provide adequate stability of the structure without these typical elements, a heel section was added to the dam.

Pine Brook and Genesee No. 2 dams also were designed to resist full hydrostatic uplift and thus the dams do not require foundation drains. Seepage through the dam foundations will drain to the downstream side.[4]

Grout curtains

High in each abutment at Hickory Log Creek Dam, partially weathered rock with numerous seams of fine-grained materials was encountered. At these locations, 20-foot-deep concrete cutoff walls were installed. A double-row grout curtain was installed for the remainder of the foundation. The grout holes were spaced at 20 feet apart and were 25 to 80 feet deep.[5]

At Elkwater Fork Dam, the grouting program consisted of a single-line curtain at the upstream heel of the dam. Grout holes were drilled from a concrete plinth after RCC placement was complete. The holes varied from 20 to 80 feet deep.6

Foundation seepage control at Pine Brook and New Big Cherry dams was limited to proper treatment at the dam/ foundation interface. Excavations for the dams extended to foundation bedrock. The rock surface was cleaned and treated with dental/leveling concrete and/or grout before RCC placement. Additionally, Pine Brook Dam included a 10-foot-wide key 5 to 10 feet deep into weathered bedrock that serves as a seepage cutoff. At Genesee No. 2 Dam, the design included a grout curtain that was installed after completion of the RCC placement. On the other hand, designers of Pine Brook Dam believed that a grout curtain could be installed after the dam was built if the seepage rate was larger than anticipated and presented a safety hazard or operational concern. However, as of September 2008, reports indicate that a grout curtain will not be needed.

Facing systems

As mentioned previously, some early RCC dams experienced significant seepage through lift joints and/or vertical cracks. As a result, many facing systems consisting of conventional concrete, precast concrete, geomembranes, and combinations thereof have been used and refined during the past two decades. Facing systems now are being used to reduce seepage and to improve durability and appearance. Detailed descriptions of the facing systems used worldwide can be found in a Portland Cement Association publication.7 A review of facing systems used on U.S. dams built after 2001 reveals that designers continue specifying facing systems that were successfully used during the 1990s.

As Table 1 shows, different types of facing systems were used on the upstream and/or downstream faces of these five dams. Conventional concrete with crack inducers and water stops at contraction joints were placed at the vertical upstream faces at New Big Cherry, Pine Brook, and Genesee No. 2 dams. The slope of the downstream faces of these dams ranged from 0.88 horizontal:1 vertical to 0.75 horizontal:1 vertical.

The design of New Big Cherry Dam included an uncontrolled ogee spillway to function as a combined service and emergency spillway. The downstream face consisted of air-entrained conventional concrete for improved freeze-thaw resistance in a harsh environment. The spillway chute incorporated steps that provided energy dissipation.

The designs and construction of Pine Brook and Genesee No. 2 dams were simplified by limiting facing systems to the upstream face and by eliminating the need for a concrete stilling basin to reduce cost. The dams were built without forming the downstream face of the RCC. Backfilling with earth to cover the unformed RCC was required after initial reservoir filling was complete. Each of these similar structures includes a concrete drop inlet and outlet works designed to pass normal flows. Larger flows up to inflow design flood can pass over an emergency spillway in the middle section of the parapet wall. The middle of the parapet wall is lower than the abutment sections to properly route the flood flow over the dam and down the vegetated earthen cover. Design engineers believed that a stilling basin was not needed based on anticipated flow characteristics and good-quality rock at the dam toe. To reduce initial cost, the owners accepted this design approach, knowing that if the emergency spillways operate, repair work likely will be needed to restore portions of the earthen covers.

The upstream face at both Hickory Log Creek and Elkwater Fork dams is formed with 6-foot-high by 16-foot-long precast concrete panels with a geomembrane fully bonded to the downstream face of the panels. Each panel is anchored to the dam with six galvanized steel rods.

The facing system on the vertical upstream face of New Big Cherry Dam in Virginia consists of conventional concrete with plywood crack inducers and water stops located at contraction joints.

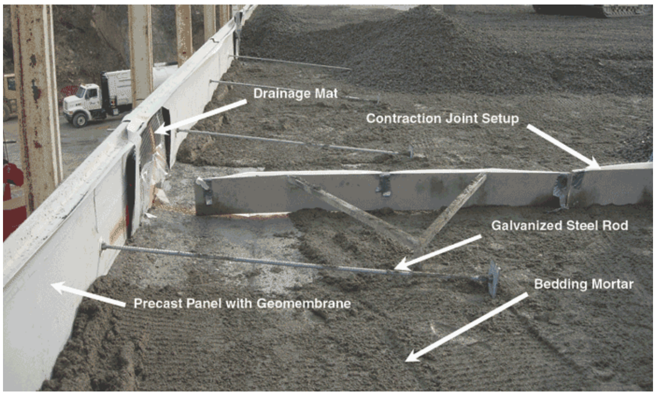
The downstream face of the chimney section at Hickory Log Creek Dam is built with decorative precast concrete panels without a membrane. The sloped downstream face is formed with 3-foot-high steps. The project team elected to use conventional concrete placed concurrently with the RCC within the spillway chute and grout-enriched RCC elsewhere. Grout-enriched RCC gave the exposed downstream steps of the dam an improved appearance compared with typical exposed RCC. A grout mix was prepared using a colloidal mixing plant at the proportions of one part portland cement to one part water (by weight). After grading the RCC but before compaction,the grout was manually poured over the top of the freshly placed RCC adjacent to the downstream wood forms. Workers then internally vibrated the grout into the fresh RCC. The RCC in this area was compacted using flat bottom plate tampers, resulting in smooth, aesthetically pleasing exposed steps.

The downstream face at Elkwater Fork Dam is formed with 2-foot-high steps. Similar to Hickory Log Creek Dam, the spillway steps are conventional concrete. However, outside the spillway training walls, the steps are formed RCC.

RCC mixtures

Producing high-quality and uniform RCC requires good and durable aggregates and good quality control. For most projects, RCC aggregates are similar to conventional concrete aggregates meeting ASTM International C33 requirements. However, marginal aggregates that did not meet all standard ASTM requirements have been used successfully where the RCC is completely protected with an air-entrained conventional concrete facing system.8

Most of the aggregates for Pine Brook and Genesee No. 2 dams were mined on-site, whereas aggregates for the other three projects were transported from rock quarries meeting ASTM C33 quality requirements. The combined aggregate gradation for Pine Brook contained 2 percent or fewer particles smaller than 2 inches. For the other dams, a smaller maximum size was used for the aggregates.



The upstream face of Hickory Log Creek Dam in Georgia is formed with 6-foot-high by 16-foot-long precast concrete panels with a geomembrane fully bonded to the downstream face of the panels. Each panel is anchored to the dam with six galvanized steel rods.

Aggregate stockpiles at Elkwater Fork Dam were built during cold weather. This stockpile management and placement of RCC during the night shift avoided the need for cooling the aggregates while placing RCC during warmer weather.

Table 2 lists the mix proportions selected. All mixes used contained Type I/II portland cement except at Genesee No. 2 Dam, where Type II was used. Class F fly ash was also used for all five projects.

One RCC mix was used for each dam, except for Elkwater Fork. Due to sliding concerns during extreme loading conditions, a cutoff key at the heel of Elkwater Fork Dam was needed to achieve adequate safety factors. Mix 1 was used above the foundation cutoff key, and Mix 2 was used in the key.

Total cementitious materials in the mixes were 250 to 310 pounds per cubic yard, and the fly ash content was 37 to 60 percent of total cementitious materials. Generally, the cementitious contents of these mixes are higher than what was used in 1980s RCC dams but comparable to the mixes used in the 1990s. As compared to those used more than ten years ago, current mixes tend to be more workable, and some contain higher fly ash contents. For larger projects, most current mix designs specify a Vebe time of 15 to 30 seconds as was the case for Hickory Log Creek and Elkwater Fork dams. Vebe time is a test performed in accordance with ASTM C1170 to evaluate the workability of the RCC mixture.

Generally, design compressive strengths for RCC gravity dams specified during this decade are 1,500 to 2,000 pounds per square inch (psi) at ages 90 days to one year. It should be noted that the design/build team for Pine Brook Dam concluded that a design based on lower design strength and conservative cross-section would provide flexibility in aggregate selection and proportions. The owner’s concerns and permit restrictions made on-site aggregate mining and crushing very attractive. About 55 percent of the aggregates were mined on site. Shortly after the successful completion of Pine Brook

Dam, on-site mining was also selected to produce RCC aggregates at Genesee No. 2 Dam.

RCC for the projects was mixed in twin, horizontal shaft, continuous pug mill mixers or in compulsory mixers. Mixer capacities were 200 to 500 cubic yards per hour. All-conveyor delivery systems were used at New Big Cherry, Hickory Log Creek, and Elkwater Fork dams. A combination of dump trucks and conveyor belts was used at Pine Brook and Genesee No. 2 dams. As has been the case for most RCC dam constructions, once on the lift surface, dozers spread the RCC and vibratory rollers compacted the material in 12-inch lifts.

Lift joint treatment

Seepage control for these dams was provided by the upstream facing systems discussed earlier, as well as by adequate lift bonding and minimizing cold joints between RCC lifts. At Pine Brook Dam, cold joints less than 14 hours required no special treatment. Cleaning and washing the surface was required for joints 14 to 36 hours old. Older joints required bedding mortar to bond consecutive lifts. Bedding mortar mix consisted of 2,800 pounds per cubic yard sand, 500 pounds per cubic yard cement, and 300 pounds per cubic yard water.

Treatment of lift joints at Hickory Log Creek Dam was required, depending on the ambient temperature and the age of the compacted RCC lift. Horizontal surfaces exposed for more than 500 degree-hours were considered cold joints and required spreading a 3/8-inch-thick bedding mortar layer just before placement of the new RCC lift. Cold joints older than 36 hours required pressure washing before spreading the bedding mortar.

Contraction joints

All five dams contained contraction joints. Generally, contractors used steel plates wrapped with polyethylene sheet to set up the joints. The steel plate is used to hold the polyethylene sheet at the desired location temporarily while the RCC is being spread. Immediately after spreading and before starting compaction of the RCC, the steel plate is removed, leaving behind the polyethylene sheet to serve as a bond breaker at the location of the contraction joint.

Conclusions

Economy and speed of construction continue to be the main reasons designers select RCC for new gravity dam construction.

Conventional concrete with contraction joints and water stops and precast concrete panels with bonded waterproofing membranes appear to be the upstream facing systems of choice for recently built dams. Conventional concrete and grout-enriched concrete are becoming more common for downstream facing systems.

Engineers continue specifying RCC mixtures similar to those used in the 1990s, which have better workability and contain relatively higher cementitious contents compared to mixes used for RCC dams in the 1980s. High paste and very workable mixes containing fly ash in the range of 40 to 60 percent of total cementitious materials are commonly specified. Additionally, higher paste mixes with smaller aggregate (nominal maximum size of 1 or 1.5 inches) are selected to reduce segregation and achieve high density. Mixes with high fly ash content have been used on a few projects worldwide to build what is referred to as "all-RCC dams."[9] The concept is to design a 100 percent RCC dam, and no other concrete mixes or auxiliary items are included to meet strength or seepage requirements. This concept, which would significantly increase the speed of construction, has yet to gain acceptance in the U.S.

Stockpiling aggregates during cold weather and placement of RCC at night can eliminate the need for costly methods that otherwise would be required to maintain the required mix temperature at time of placement. The stockpiling management approach used at Elkwater Fork Dam should be considered for RCC gravity dam construction.

Perhaps the most notable development in recent RCC gravity dams in the U.S. is the design approach implemented at Pine Brook and Genesee No. 2 dams. The following design features resulted in significant effects on the Pine Brook Dam speed of construction and total cost:

– Increasing the dam size to reduce the required RCC strength provided an opportunity to use on-site aggregates of marginal quality. Aggregates that fail to meet certain ASTM requirements still may be used if appropriate tests are performed and the results show that the aggregates can produce RCC meeting the project requirements;

– Building the dam without forming the RCC on the downstream face and covering the unformed RCC with soil provided protection against freeze-thaw action;

– Designing the dam to resist full hydrostatic uplift pressure eliminated the need for foundation drains and a drainage gallery; and

– Eliminating the construction of a stilling basin saved money and time. n

Mr. Abdo may be reached at Portland Cement Association, P.O. Box 26381, Birmingham, AL 35260; (1) 205-979-9435; E-mail: fabdo@cement.org.

Notes

1. Hansen, K.D., "Roller-Compacted Concrete: A Civil Engineering Innovation," Concrete International, Volume 15, No. 3, March 1996.

2. Smoak, W.G., "Crack Repairs to Upper Stillwater Dam," Concrete International, Volume 13, No. 2, February 1994, pages 24-32.

3. Cowan, G.L., K.A. Ferguson, and Fares Y. Abdo, "New RCC Dam Replaces 70-Year Old Concrete Dam," Portland Cement Association Publication PL464, Skokie, Ill., 2006.

4. Shannon, D.A., J.C. Allen, and R.D. Hass, "Design/Build Approach Big Success for Pine Brook RCC Dam," Portland Cement Association Publication PL466, Skokie, Ill., 2007.

5. Parsons, James M., Randall P. Bass, Charles M. Kahler, and Rodolfo T. Ruiz-Gaekel, "Hickory Log Creek: Building a Roller-Compacted-Concrete Dam," Hydro Review, Volume 27, No. 1, March 2008, pages 36-45.

6. Holderbaum, R.E., R.L. Judy, and P.G. Schweiger, "Elkwater Fork Dam," Portland Cement Association Publication PL468, Skokie, Ill., 2008.

7. Facing Systems for Roller Compacted Concrete Dams & Spillways, Portland Cement Association, Skokie, Ill., 2001.

8. Gaekel, L., and Ernest K. Schrader, "RCC Mixes and Properties Using Poor Quality Material - Concepcion Dam," Roller-Compacted Concrete III, American Society of Civil Engineers, New York, 1992.

9. Ortega, F., "Alternative Designs," International Water Power & Dam Construction, Volume 59, No. 7, July 2007, pages 14-18.

Fares Abdo, P.E., is program manager for water resources with the Portland Cement Association. He provides technical support and develops literature on roller-compacted concrete and soil-cement for water resources applications.

µ Peer Reviewed

This article has been evaluated and edited in accordance with reviews conducted by two or more professionals who have relevant expertise. These peer reviewers judge manuscripts for technical accuracy, usefulness, and overall importance within the hydroelectric industry.

(Hydro Review, Vol. 27, Issue 7, November 2008, http://www.hydroworld.com/articles/hr/print/volume-27/issue-7/technical-articles/roller-compacted-concrete-dams-design-and-construction-trends.html)

-

drone

https://www.youtube.com/watch?v=GmIh0nPG-CU

Facebook

-

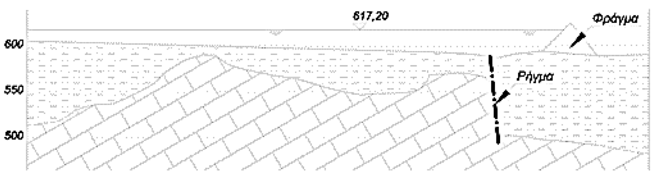
..

video -

3

3

- -



-

-

-

.

-

»,
http://portal.tee.gr/portal/page/portal/teelar/EKDILWSEIS/damConference/eisigiseis/7.2.pdf)

Hundreds dead or missing after dam collapse in Attapeu, southeastern Laos

Hundreds of people are dead or missing after an under construction dam collapsed in southeastern Laos late Monday, July 23, 2018.

According to Laos News Agency, several hundred people are missing after a hydroelectric dam in Sanamxay district of A t - tapeu province collapsed late Monday, sending fast-moving water through six villages, including Yai Thae, Hinlad, Mai, Thasengchan, Tha Hin, and Samong.

h t t p s : www. o u t u b e . c o m watch t i me NKdN2riOE

h t t p s : www. o u t u b e . c o m watch t tinue=1&v=JLv4GMAgJNU

Hinlad and Mai villages are reportedly the hardest-hit.

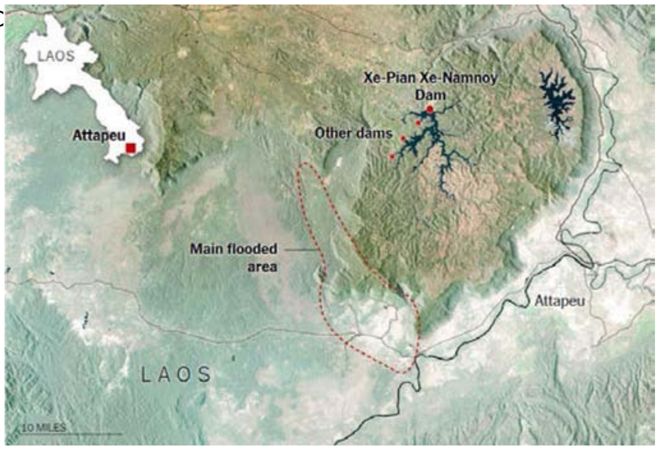
T h e c o l l a p s e r e p o r t e d l r e l e a s e d 5 b ter, destroying numerous homes and leaving more than 6 600 people homeless, the agency said.

The reason for the collapse is still not clear.

The dam is being built by Xe Pien-Xe Namno Power C
pany and is a joint project between several South Korean and Laos companies.

The construction of this 410-megawatt capacity dam began in 2013 and the plant was supposed
erations by 2019, with 90% of its electricity sent to Thailand.

(THE WATCHERS, July 24, 2018, [https: watch-ers.news/2018/07/24/hundreds-dead-or-missing-after-dam-collapse-in-attapeu-southeastern-laos utm source eedburner utm me-dium email utm cam-paign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29](https://watchers.news/2018/07/24/hundreds-dead-or-missing-after-dam-collapse-in-attapeu-southeastern-laos))



Laos Dam Collapse Leaves Hundreds Missing and Homes Washed Away

A hydroelectric dam that was under construction failed on Monday, killing several people and flooding villages in the southern province o Attapeu. Over 6,600 people were dis-
placed and hundreds more were missing.

The wall of water, unleashed by a dam failure, roared through a half-dozen rural villages in Laos, sweeping away hundreds of people in its torrents.

On Tuesday, many of those people were nowhere to be found, and while only several people have been confirmed killed, Laotian officials feared the worst.

The dam, which was still under construction, gave way on Monday, forcing nearly 7,000 people to flee their homes.

Photos and videos rom the scene sh
ter covering a vast area, with residents seeking refuge on rooftops that barely remained dry. Others could be seen walkin knee deep in water out o the looded area or escap-
ing on boats with only a few possessions in hand.

The dam was part of a billion-dollar hydropower project that the aotian overnment sees as crit
opment. Opponents argued that the risks to local people and to fisheries did not justify the economic benefits.

The failure of the structure, one of the smaller of more than a half-do en dams bein built on three the Me-
kong River in Laos, released about 175 billion cubic feet of water, washin awa homes in the so At-
tapeu, near the border with Vietnam and Cambodia.

The state news agency did not give an exact death toll, but it is feared the number will grow, with the search for victims in the devastated area still in its early stages.

Though the flooding was widely described as a result of a dam collapse, the South Korean company building the dams, SK Engineering & Construction, said it was investigating whether the structure failed or whether water swept over it as a result of heavy rain. The rainfall was three times heavier than normal, according to the Yonhap News Agency in South Korea.

The company sent helicopters, boats and personnel to aid rescue operations, the South Korean Foreign Ministry said in a statement.

The project — which includes three major dams in addition to at least three smaller auxiliary dams, or saddle dams, like the one that failed — is designed to generate electricity from the water of three rivers, which all ultimately flow into the Mekong.

The electricity is to be produced in southern Laos, but 90 percent is to be purchased by Thailand. The project, begun in 2013, was scheduled to begin operation next year.

The damming of the Mekong and its tributaries has been highly controversial.

The Mekong stretches about 2,700 miles from the Tibetan Plateau in China to the vast Mekon
ing along the borders of Myanmar and Thailand and flowing through Laos, Cambodia and Vietnam before spilling into the South China Sea.

China, Laos and Cambodia have begun massive hydroelectric development programs, with more than a dozen dams planned, under construction or completed on the main river and many more dams on tributaries.

Laos, a landlocked, communist state that is largely isolated from the rest of the world, is one of Asia's poorest countries. Its leaders see harnessing hydroelectric power as key to growth.
Opponents fear that damming the Mekong River will cause greater economic harm than good by destroying fisheries and damaging the delta's rich farming region, which depends on the flow of sediment from the upper stretches of the river.

"If all of these projects are built, they will transform one of the world's most iconic rivers, and
sit river lobal , into a series
carygroup International Rivers.

The electricity the dams generate can serve growing urban popula tions and provide a inancial b
cials, power ul militaries and ian
tional development agencies often agree to partially finance the dams, despite concerns about corruption, in part because hydroelectric power is seen as preferable to coal-power plants and other fossil fuel projects that contribute to global warming.

But man independent studies have d
dropower projects in Southeast Asia — especially large ones — directly contribute to erosion, the decimation of fish stocks and biodiversity, and the further impoverishment of rural communities that are forced to leave the dam sites and move to less-fertile land.

The collapse of the dam Monday was not the first in Laos. Last year, a dam on the Nam Ao River that was being built as part of a hydropower project burst, although no deaths were reported after that accident.

On Tuesda , the state news a enc r
ister Thongloun Sisoulith of Laos suspended a government meeting and led members of his cabinet to monitor rescue and relief efforts.

The 410-megawatt dam is being built by the Xe-Pian Xe-Namnoy Power Company, a joint venture that includes two companies from South Korea, one from Thailand and one from Laos.

SK E & C, one of those South Korean companies, is an affiliate of SK Group, one of South Korea's largest business conglomerates, and has built power plants at home and abroad.

The project is expected to generate approximately 1,879 gigawatt hours of electricity a year, the Xe-Pian Xe-Namnoy Power Company says on its website.

The phone lines of the Xe-Pian Xe-Namnoy Power Company's two offices in Laos were either busy or rang unanswered on Tuesday.

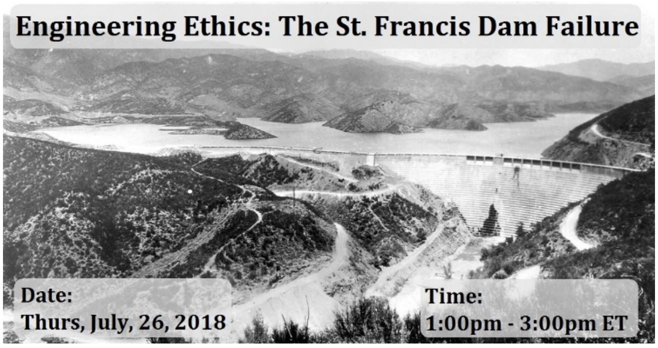
Some residents whose villages were in the way of the hydropower project have resisted moving, saying the compensation they were offered was too small and the land they were offered was unsuitable for farming.

In a 2013 letter to the power company, International Rivers said its staff had visited the resettlement zone for the dam and seen firsthand that people there were struggling "with a lack of access to sufficient food, water and land."

"In addition, families have found that the shallow soil around their homes is inappropriate for growing vegetables, fruits or staple crops, and consistently attest to going hungry," the letter said.

(Richard C. Paddock and Mike Ives / Mew York Times, Choe Sang-Hun contributed reporting from Seoul, South Korea, and Muktita Suhartono from Jakarta, Indonesia, July 24, 2018, https://www.nytimes.com/2018/07/24/world/asia/laos-dam-collapse-hundreds-missing.html).

The St. Francis Dam Failure



(φωτογραφία από την ανακοίνωση του webinar για την αστοχία του φράγματος)

The structural failure of the St. Francis Dam is considered by many to be one of the top ten worst engineering disasters of all time and rated the worst overall civil engineering disaster in the state of California. When the dam collapsed, the water that was unleashed created a 2-mile wide, 50-mile long course of devastation that began in the San Francisquito Canyon reaching all the way to the Pacific Ocean at Ventura. The dam collapse, which occurred on March 12th, 1928, released 15-billion gallons of water in the form of a 140-foot high wave; that wave picked up debris and mud as it travelled down the Santa Clara River Valley at an average speed of 12-mph. The failure of the dam caused the death of at least 450 people and the loss of property estimated at over $20,000,000 (in 1928 dollars).

The construction of the St. Francis Dam was directed by William Mulholland, Superintendent and Chief Engineer for the Los Angeles Department of Water and Supply (aka LA's Bureau of Water Works and Supply). Mulholland was not formally trained nor educated as an engineer; he can best be described as a "self-taught" engineer. When his career in water supply first began in 1878, Mulholland was employed as a ditch cleaner for a private water supply company in Los Angeles, California. Eight short years later, Mulholland became the Superintendent of that privately owned water supply company. When the city took over the water system, Mulholland was retained as the Superintendent and Chief Engineer for the LA Department of Water and Supply.

One of the major accomplishments of Mulholland's career was the role he played in the conception, design and construction of the Los Angeles Aqueduct, which was completed in 1913. Mulholland, along with the former mayor of Los Angeles, Mr. Fred Eaton, envisioned the need for water to support the rapidly growing and expanding population of the Los Angeles region. The construction of the aqueduct was part of their plan to provide water to the Los Angeles area.

In the early 1920's, the Los Angeles area suffered a drought. To provide additional water resources for the area, Mulholland proposed a five-year plan that called for the construction of eight new dams. The construction of St. Francis Dam and the reservoir were part of that plan providing additional water to support the growing need of the community.

The St. Francis Dam, which spanned the San Francisquito Canyon approximately 35-miles to the north and west of Los Angeles, was a curved concrete gravity/arch structure that was approximately 210 feet high with a 500-foot radius of curvature and a maximum base width of approximately 140-feet. During the construction phase, the height of the dam was increased approximately 20-feet to increase the amount of retained water; unfortunately, the base width of the dam was not adjusted accordingly.

When the dam was completed in 1926 and the reservoir was being filled (1926 through March 1928), cracks in the concrete structure were immediately observed. Mulholland attributed those cracks to concrete curing. New cracks and subsequent leaks continued to be observed throughout the filling process. However, Mulholland continued to state that the structure of the dam was "sound". On the day of the collapse, the dam keeper contacted Mulholland and reported a newly developing larger leak in the structure. On March 12th, 1928 at approximately 12 noon, Mulholland personally inspected the dam and assured the dam keeper that the St. Francis Dam was structurally sound. Approximately 12-hours later, at 11:57 pm, the St. Francis Dam catastrophically failed.

A board of inquiry blamed Mulholland for ignoring signs that the St. Francis Dam was leaking dangerously. Mulholland, who faced criminal prosecution by the LA County District Attorney, finally accepted responsibility for the collapse stating "Don't blame anyone else. Whatever fault there was on the job, put it on me." Mulholland was forced to resign in disgrace soon after the incident.

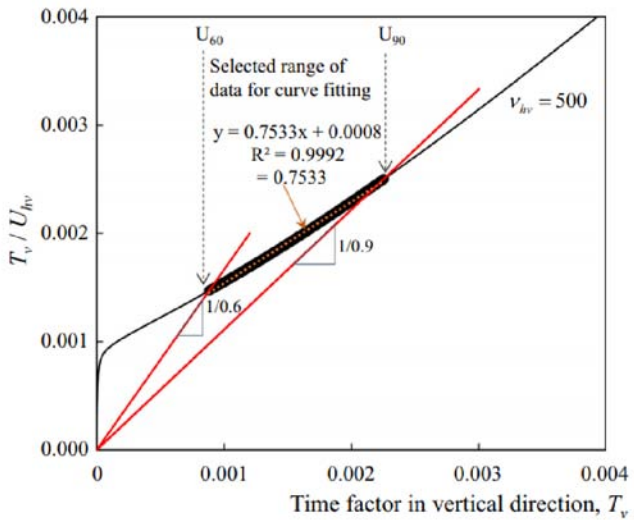
(https://www.pdhengineer.com/catalog/index.php?route=product/product&product_id=3129)

GEOTECHNICAL JOURNALS

Monthly Review of Geotechnical Journals - Up to July

I have been following many geotechnical journals for some time and I have thought that sharing some of the papers that I have interested would be a ood idea. It would be a per-sonal note to answer "Where did I see this?" and a way to share updates with geotechnical community. The selected papers are solel based on m research and professional in-terest, therefore, you may miss some of the good stuff still. But, these short summaries will help you even thou h. Alt-hough I have written "Up to July" in the headline, as most of the journals publish beforehand, you should interpret this as "papers I have access up to July". For example, September 2018 issue of Journal of Geotechnical and Geoenvironmental Engineering is already out there and I have included all the materials that were published. I hope to publish these re-views every one or two month if I get the time.

[Guo, W., Chu, J., & Nie, . (2018). esi n chart or ified hyperbolic method. Soils and Foundations, 58(2), 511-517.]()



There are several methods to estimate the final consolidation settlement if you have observed the settlements up to a time after loading. Asaoka method is one of the most common and I have used it before for embankments and buildings. See Asaoka (1978) and Mesri & Huvaj-
for details. One of the other methods is hyperbolic method and modi ied h perbolic method. This paper develops a sim-pler approach to use modified hyperbolic method with drains to accelerate settlement. Authors state they have reduced the many parameters into single parameter, v_{hv}, which is the ratio o time actors in horizontal and vertical directions. Us-ing this parameter and observed settlement-time data, it is easier to estimate complete settlement vs. time graph. e-member this paper if you have highly consolidating soils.

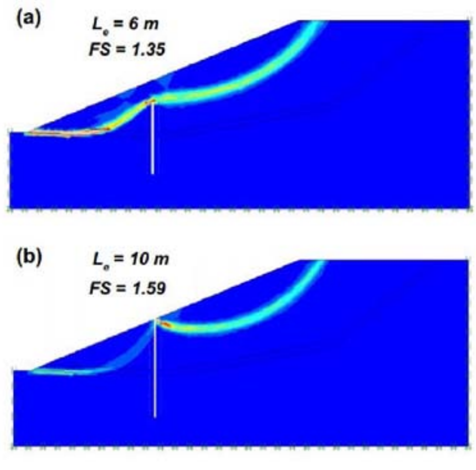
[Cunha, . P., Poulos, H. G. (2018). cavation Level on the Prediction of the Settlement Pattern from Piled Raft Analyses. SOILS AND ROCKS, 41(1), 91-99.]()

Althou h Brail's Soil and ocks ou ian Association or Soil Mechanics a ing and Portuguese Geotechnical Society) was not on my watchlist (it is now!), my special attention to Prof. Poulos' works have led me to there. Cunha and Poulos' study is on a topic I have special interest for: Compensated piled rafts. They have analyzed a rather not-well-documented case of Hansbo. Using simplified approach to model compensation e ects, i.e. reducin buildin loa served settlements with a Class-C prediction. Soil and Rocks is an open-access journal and related issue can be reached from [here.]()

[Poulos, H. G. (2018). A review of geological and geotechnical features of some Middle Eastern countries. Innovative In ra-structure Solutions, 3(1), 51.]()

Poulos, a ain. He presents a per ec ence and literature review o the pu otechnical and geological on Middle Eastern countries. If you ever have a project in Middle East, make sure you have read this paper.

[Zhao, S., en , . (2018). Anal s inforced landslides using strength reduction finite element method. International Journal of Geotechnical Engineering, 12(4), 389-401.]()



8 Critical slip surfaces at L_e of a 6 m and b 10 m

Zhao and Deng presents effective length approach for piles to support landslides. I was not awa ever, authors have conviced me to i ded piles" in the headline is not embedded beams we know from FEM, but piles below the ground level. They introduce effective length of pile, which is the length of the pile above the shear band (failure surface). They have presented a scheme to obtain the optimum effective pile length and used this scheme to improve a real landslide. Authors also claim that bendin moment and lateral or ing optimum pile lengths instead of full length.

[McGann, C. R., Bradley, B. A., & Jeong, S. (2018). Empirical Correlation for Estimating Shear-Wave Velocity from Cone]()

Penetration Test ata or Banks Peninsula Loess Soils in Canterbury, New Zealand. Journal of Geotechnical and Geoenvironmental Engineering, 144(9), 04018054.

This new correlation is developed using multiple linear regression with the same functional form and general procedure used by McGann et al. (2015b) to create the Christchurch-specific general soil CPT-V_s model. The following loess-specific median CPT-V_s empirical prediction equation was obtained through this process:

$$V_s = 103.6 q_t^{0.0074} f_s^{0.130} z^{0.253} \quad (6)$$

where q_t and f_s = pore pressure–corrected tip resistance and sleeve frictional resistance, respectively, at depth z (q_t and f_s in kPa; z in m; V_s in m/s).

McGann et.al. develops a "loess-specic correlation ... mating shear wave velocity using CPT. They have collected seismic piezocone (SCPTu) data from 26 loess site in Banks Peninsula, Christchurch, New Zealand. Although we have PEER's extensive collection of Vs correlations, it is important to have loess-specific correlation since these soils are most problematics both for settlement and liquefaction.

Zhang, F., Leshchinsky, D., Gao, Y., & Yang, S. (2018). Three-imensional Slope Stabilit Analing Corners. Journal of Geotechnical and Geoenvironmental Engineering, 144(6), 06018003.

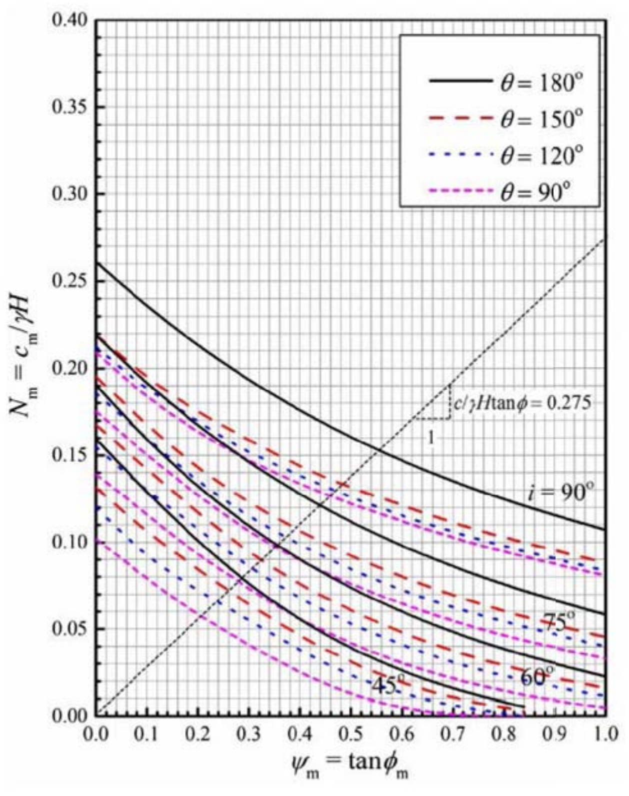


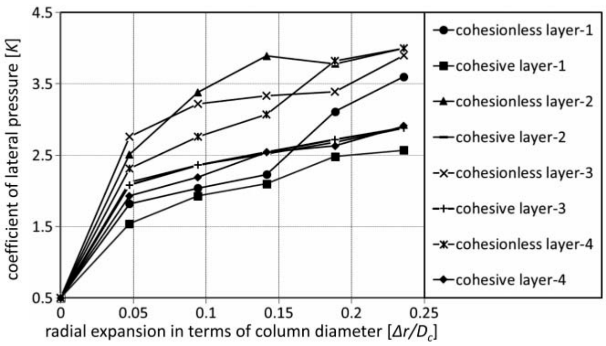
Fig. 2. Stability chart for corner slopes under static condition.

Authors have presented results o 3 limit equilibrium analyses for convex corners of a slope. One interesting conclusion I was really impressed was the following: "...the calculated results demonstrate that even a slight decrease of the turning angle from 180, representin practical geometrical imperfection, will yield failures having well-defined length. It could be one reason why observed failures have **distinctive limited length** in **seemingly long straight homogenous slopes.**" I think an experienced geotechnical engineer would most be seen also in u stabilit in the slope. However, these concl portant to understand some cases.

Teng, F., Arboleda-Monsalve, L. G., & Finno, R. J. (2018). Numerical Simulation of Recent Stress-History Effects cavation Responses in Soft Clays. Journal of Geotechnical and Geoenvironmental Engineering, 144(8), 06018005.

In their paper, Teng et. al. proved the effect of stress-history on the excavation deformation and ground settlement behind excavation usin hypoplasticity mod est, I haven't observed anything new in this paper since we are aware of the effect of histor o the soil on nical performance since Simpson's brick model, even before it. However, since this is a technical note, it is nice to see the same results with hypoplasticity model.

Al Ammari, K., & Clarke, B. G. (2018). Effect of Vibro Stone-Column Installation on the Performance of Reinforced Soil. Journal of Geotechnical and Geoenvironmental Engineering, 144(9), 04018056.



Al Ammari and Clarke presents a cavity expansion approach to model stone column installation effects. They model stone columns using cavity expansion theory in Plaxis 2D and using the data from 2D analyses, they analyze a case using Plaxis 3D. Their results indicate that coeficient o lateral sure and stiffness may increase up to 6D distance where D is the column diameter. Using this approach, stiffer response, thus less settlement is obtained. Calculated results agree with the observed settlements.

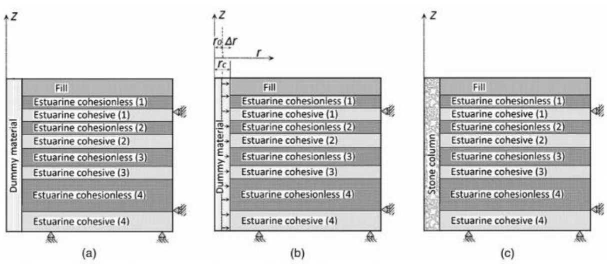
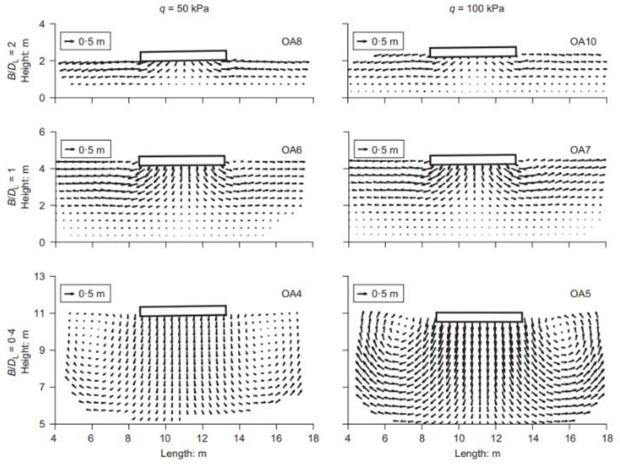


Fig. 4. Principle of stone column expansion using the dummy material and modeling phases.

Kumar, S., & Basudhar, P. K. (2018). A Neural Network Model for Slope Stability Computations. Géotechnique Letters, 1-20.

Kumar and Basudhar developed a neural network to predict factor of safety of a slope. They introduced a formula using weights and bias functions of their model too. R2 values show that simple slope stability problems can be modeled using ANN with a high accuracy.

[Adamidis, O., & Madabhushi, S. P. G. (2017). Deformation mechanisms under shallow foundations on liquefiable layers of varying thickness. Géotechnique.]



Authors have compared centrifuge test results of buildings on liquefiable layers with common methods to estimate building settlements. Their results show that these common methods such as Tokimatsu & Seed (1987), Liu & Dobry (1997) etc. "failed to offer reliable values." They also note that for deep layers, soil moves downward or depth o B and moves laterally below that point. For shallow layers, soil moves laterally to cause settlement, similar to bearing capacity failure. They also note that Bertalot et. al. (2013) method to estimate upper limit of settlement were valid or the measured settlement below the building.

Books

Highly respected Arnold Verruijt from Delft have published "[An Introduction to Soil Mechanics]" which is an extension of his previous lecture notes on this topic. Title may be misleading since this is definitely not an entry level introduction, however, Verruijt's insights on the soil mechanics, as well as on the Computational Geomechanics, carr reat importance.

Although I have several, I am always happy to see correlation books. These are life savers during tight scheduled design works. Verbrugge and Schroeder have published [Geotechnical Correlations for Soils and Rocks"]. I haven't got the chance to see the full book yet, however, quick look is very promising.

(Berk Demir, July 3, 2018, https://www.linkedin.com/pulse/monthly-review-eotechnical-journals-up-july-berk-demir/)

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

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

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

China- Europe Conference on Geotechnical Engineering, 13-16 August 2018, Vienna, Austria, https://china-euro-geo.com

International Symposium on Seismic Performance and Design of Slopes, 18 ÷ 19-08-2018, Shanghai, P.R. China, http://geotec.tongji.edu.cn/show.aspx?info_lb=328&flag=190&info_id=1424

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

Hydropower Development 2018, 5 - 6 September 2018, Zurich, Switzerland, www.wplgroup.com/aci/event/hydropower-development-europe

EUCEET 2018 - 4th International Conference on Civil Engineering Education: Challenges for the Third Millennium, 5-8 September 2018, Barcelona, Spain, http://congress.cimne.com/EUCEET2018/frontal/default.asp

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

26th European Young Geotechnical Engineers Conference, 11 - 14 September 2018, Reinischkogel, Austria, www.tugraz.at/en/institutes/ibg/events/eygec

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

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

International Conference on Geotechnical Engineering and Architecture URBAN PLANNING BELOW THE GROUND LEVEL: ARCHITECTURE AND GEOTECHNICS, 19-21 September 2018, Saint Petersburg, Russia, http://tc207ssi.org

International Symposium on Energy Geotechnics SEG - 2018, 25-28 September 2018, Lausanne, Switzerland https://seg2018.epfl.ch

1st International Conference TMM_CH Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage, 10-13 October, Athens, Greece, www.tmm-ch2018.com

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

GEC - Global Engineering Congress Turning Knowledge into Action, 22 - 26 October 2018, London, United Kingdom, www.ice.org.uk/events/global-engineering-congress

ISEV 2018 CHANGSHA The 8th International Symposium on Environmental Vibration and Transportation Geodynamics & the 2nd Young Transportation Geotechnics Engineers Meeting, October 26–28, 2018, Changsha, China, www.isev2018.cn

8th International Congress on Environmental Geotechnics "Towards a Sustainable Geoenvironment", 28 October to 01 November 2018, Hangzhou, China, www.iceg2018.org

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

UNSAT Oran 2018 4ème Colloque International Sols Non Saturés & Construction Durable, 30-31 October 2018, Oran, Algeria, www.unsat-dz.org

Energy and Geotechnics The First Vietnam Symposium on Advances in Offshore Engineering, 1-3 November 2018, Hanoi, Vietnam, https://vsoe2018.sciencesconf.org

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

ISRBT2018 International Seminar on Roads, Bridges and Tunnels - Challenges and Innovation, 9-15 November 2018, Thessaloniki, Greece, http://isrbt.civil.auth.gr

International Symposium Rock Slope Stability 2018, 13-15 November, 2018, Chambéty, France, www.c2rop.fr/symposium-rss-2018

GeoMEast 2018 International Congress and Exhibition: Sustainable Civil Infrastructures, 24 - 28 November 2018, Cairo, Egypt, www.geomeast.org

AR AUSROCK The Fourth Australasian Ground Control in Mining Conference, 28–30 November 2018, Sydney, Australia, http://ausrock.ausimm.com

Second JTC1 Workshop on Triggering and Propagation of Rapid Flow-Like Landslides, 03-05 December 2018, Hong Kong, Email: ceclarence@ust.hk

13th Australia New Zealand Conference on Geomechanics 2019, 01 ÷ 03-04-2019, Perth, Australia, http://geomechanics2019.com.au

AFRICA 2019 Water Storage and Hydropower Development for Africa, 2-4 April 2019, Windhoek, Namibia, www.hydropower-dams.com/pdfs/africa19.pdf

IICTG 2019 2nd International Intelligent Construction Technologies Group Conference "Innovate for Growth, Collaborate for Win-Win", 23-04-2019 - 25-04-2019, Beijing, China, www.iictg.org/2019-conference

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

2019 Rock Dynamics Summit in Okinawa, 7-11 May 2019, Okinawa, Japan, www.2019rds.org

15th International Congress of the Geological Society of Greece
Athens, 22-24 May 2019

www.gsg2019.gr

GSG 2019 will take place on May 22-24, 2019, in Athens, capital of Greece. The International Congresses of the Ge o - logical Society of Greece are multidisciplinary earth science events, focusing on, but not limited to, the broader Aegean region and its surroundings, with the view to highlighting the contribution of geosciences to the study of natural resources, natural hazards and environment.

GSG 2019 aims at bringing together geoscientists from all o v e r t h e w o r l d a n d t o p r o v i d i n a o r u m w h e r e s c i e n t i s t s , e s - pecially early career researchers, will present their research work in all fields of geosciences.

The Congress is organized in thematic/technical sessions and topics. Sessions can be modified, combined or a new session could be opened, depending on the range and the scientific focus of the submitted abstracts. All sessions are grouped under the general thematic headers as follows:

T1. Stratigraphy, Palaeontology and Sedimentology
T2. Geodynamics, Tectonics and Structural Geology
T3. Geophysics and Seismology
T4. Geochemistry, Mineralogy, Petrology, Volcanology and Geothermy
T5. Geomorphology, Quaternary Geology and G e o a r c h a e o l - ogy
T6. Economic Geology and Energy Resources
T7. Natural Hazards
T8. Marine Geology and Oceanography
T9. Engineering Geology, Hydrogeology and Environmental Geology
T10. Geology and Society: Geo-environmental education and Sustainability, Geological Heritage
T11. G e o i n o r m a t i c s : e m o t e S e n s i n a n d I n o r m a t i o n T e c h - nology in Geosciences
T12. Atmospheric Sciences

Contact Information

5, Adrianoupoleos str.
55133 Thessaloniki, Greece
+30 2310-223461
e-mail: info@nbevents.gr

Organizer website

https://nbevents.gr

Underground Construction Prague 2019, June 3–5, 2019, Prague, Czech Republic, www.ucprague.com

VII ICEGE ROMA 2019 - International Conference on Earthquake Geotechnical Engineering, 17 - 20 June 2019, Rome, Italy, www.7icege.com

ICONHIC2019 - 2nd International Conference on Natural Hazards and Infrastructure, 23-26 June 2019, Chania, Crete Island, Greece, https://iconhic.com/2019/conference

IS-GLASGOW 2019 - 7 t h I n t e r n a t i o n a l S mp o s i mation Characteristics of Geomaterials, 26 - 28 June 2019, Glasgow, Scotland, UK, https://is-glasgow2019.org.uk

cmn 2019 -Congress on Numerical Methods in Engineering, July 1 - 3, 2019, Guimarães, Portugal, www.cmn2019.pt

The 17th European Conference on S o i l M e c h a n i c s a n otechnical Engineering, 1st - 6th September 2019, Reykjavik Iceland, www.ecsmge-2019.com

3 r d I n t e r n a t i o n a l C o n e r e n c e C h a l l e gineering" CGE-2019, 10-09-2019 - 13-09-2019, Zielona Gora, Poland, www.cgeconf.com

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

3rd ICTITG I n t e r n a t i o n a l C o n e r e n c e o n I n ogy in Geo-Engineering, Sep. 29-02 Oct., 2019, Guimarães, Portugal, www.3rd-icitg2019.civil.uminho.pt

11th ICOLD European Club Symposium, 2 - 4 October 2019, Chania Crete – Greece, www.eurcold2019.com

4

, -

2019, www.eltam.org

XVII African Regional Conference on Soil Mechanics and Geotechnical Engineering
07 -10 October 2019, Cape Town, South Africa

T h e S o u t h A r i c a n I n s t i t u t i o n o C i v vites all our colleagues from Africa and beyond to attend the 1 7 t h A r i c a n e i o n a l C o n e r e n c e o n otechnical Engineering.

H o s t e d i n o n e o t h e c o n t i n e n t ' s m o ference will serve practitioners, academics and students of all geotechnical backgrounds. The conference will take place at the Cape Town International Convention Centre (CTIC C) o - fering world class conferencing facilities in the heart of South Africa's mother city and will offer extensive opportunities for T e c h n i c a l C o m m i t t e e M e e t i n s , o r k s bitions and Sponsorships. Exciting Technical Visits, including tours to the famous Robben Island, await.

The 7th African Young Geotechnical Engineers' Conference (8 – 10 October 2019) will commence on 8 October 2019, the day following the African Regional Conference (ARC) opening. The conference venue will be shared with the ARC delegates to initiate dialogue between junior and senior engineers while young geotechnical engineers acquaint themselves with the i n d u s t r s t a n d a r d s , n e w e o t e c h n i c a sources available to further their careers. The YGE conference p r o v i d e s a n a p p r o a c h a b l e a u d i e n c e w me n t w h e r e o u n p r e s e n t e r s u n d e r t couraged to exercise their presentation and technical writing skills on a continental platform.

Organiser: SAICE
Contact person: Dr Denis Kalumba
Email: denis.kalumba@uct.ac.za

X I Asian e ional Con erence on Soil Mechanics and Ge-otechnical Engineering, 21 - 25 October 2019, Taipei, China
www.16arc.org

X I Panamerican Con erence on Soil M nical Engineering, 18-22 November 2019, Cancun, Quintana Roo, Mexico, http: panamerican20 ico.com/panamerican

YSRM2019 -the 5th ISRM Young Scholars' Symposium on Rock Mechanics
and
REIF2019 -International Symposium on Rock Engineering for Innovative Future
1 4 December 2019, Okinawa, Japan

Contact Person: Prof. Norikazu Shimizu, jsrm-o ice rock-net-japan.org

14th Baltic Sea Geotechnical Conference 2020
25 ÷ 27 May 2020, Helsinki, Finland

Organiser: Finnish Geotechnical Society
Contact person: Leena Korkiala-Tanttu
Email: leena.korkiala-tanttu@aalto.fi
Website: http://www.ril.fi/en/events/bsgc-2020.html
Email: ville.raassakka@ril.fi

Nordic Geotechnical Meeting
27 29 May 2020, Helsinki, Finland

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

EUROCK 2020
Hard Rock Excavation and Support
June 2020, Trondheim, Norway

Contact Person: Henki Ødegaard, henki.oede aard multi-consult.no

Geotechnical Aspects of Underground Construction in Soft Ground
29 June to 01 July 2020, Cambridge, United Kingdom

Organiser: University of Cambridge
Contact person: Dr Mohammed Elshafie
Address: ain O' ourke Centre, epartment o En ineering, Cambridge University
Phone: +44(0) 1223 332780
Email: me254@cam.ac.uk

16th International Conference of the International Association for Computer Methods and Advances in Geomechanics – IACMAG
29-06-2020 ÷ 03-07-2020, Torino, Italy

Contact Information

Contact person: Symposium srl
Address: via Gozzano 14
Phone: +390119211467
Email: info@symposium.it, marco.barla@polito.it

www.eurogeo7.org

We are pleased to invite you to the 7th EuroGeo conference, to be held in Warsaw, Poland in 2020. Poland is a country with more than a thousand years of recorded history and has a strong European identity. The country was first to free itself rom communist domination in 1989 and is now ull demo-cratic and a member of the European Union. Poland is a leader in infrastructure development in the region, which has resulted in many extraordinary projects. Warsaw, with its central location, is an ideal base for exploring the country. Today, the city is a dynamic cultural and business centre, with strong links not only to Western Europe but also to the East. PSG-IGS, a Polish Chapter of IGS is young but thriving organization successfully cooperating with several chapters within Central Europe. It is an honour to host such a presti-ious conference in Warsaw and we sincerely believe that the sessions will prove to be a success. Come to Warsaw, bring your family and enjoy your stay in our capital and help us to make this Conference not only scientifically profitable but also an unforgettable event.

Contact: eurogeo7inpoland@gmail.com

6th International Conference on Geotechnical and Geophysical Site Characterization
07-09-2020 ÷ 11-09-2020, Budapest, Hungary
www.isc6-budapest.com

Organizer: Hungarian Geotechnical Society
Contact person: Tamas Huszak
Address: Muegyetem rkp. 3.
Phone: 0036303239406
Email: huszak@mail.bme.hu
Website: http://www.isc6-budapest.com
Email: info@isc6-budapest.com

5TH World Landslide Forum Implementation and Monitoring the USDR-ICL Sendai Partnerships 2015-2015, 2-6 November 2020, Kyoto, Japan, http://wlf5.iplhq.org

(THE WATCHERS, July 10, 2018, h t t p s : watch-ers.news/2018/07/10/culvert-failure-causes-major-train-derailment-t u r k e u t m s o u r c e e e d b u r n e r d i u m e mai l ut m c a m-paign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29)

Culvert failure causes major train derailment, Turkey

A major train accident took place in Turkey's province on July 8, 2018, after the ground between the culvert and the rail collapsed due to heavy rain . I n to-tal, 24 people were killed and 73 injured. The train was carrying more than 360 passengers.

While local media widely reported the accident as a result of a small landslide triggered by heavy rain, other reports s u -gested a culvert failure, which seems more likely.

As reported by Dr. Dave Petley of The Landslide Blog, the derailment 'seems to have r e s u l t e d r o m t h e c o l l taining wall above a culvert on the rail embankment, which has allowed the ground and ballast to slip from under the rails.'

Presumably, Petley writes, this is the culvert for the stream that is shown in the first image, just behind the last derailed carriage.

The image below shows the distortion of the rails and the collapse of the sleepers that presumably occurred as the train crossed the slipped section of the embankment.

"While landslide-induced rail accidents are not unusual, the remarkable thing about this tragedy is that it was caused by such a small geotechnical failure," Petley said. "The amount of ground that has shifted is probably a few cubic meters."

I n t o t a l , 24 p e o p l e w e r e k i l l e d a n d 73 i n u r e d , T u r k i s h a u -t h o r i t i e s s a i d , a d d i n t h a t i v e o t h e t r a i n ' s s i c a r s d e-railed after ' t h e r o u n d b e t w e e n t h e c u l v e r t a n d t h e r a i l c o l -lapsed' due to heavy rain.

Istanbul building in spectacular collapse after heavy rains

Municipality officers stand by the four-s t o r e b u i l d i n tanbul’s Sutluce district as it collapses.

A four-storey residential building in central Istanbul collapsed yesterday in a cloud of dust in front of watching media, after several hours perching on a ledge following heavy rains that destroyed its foundation.

The building, in the Sutluce district of the Beyoglu n e i h b o u r -hood, had been left stranded with several metres of its base poking over the edge after the overnight downpours washed away its base.

The image of the building seemingly defying gravity for two hours as it perched on the edge of the ground attract e d c a m-era crews, municipal workers and members of the security forces.

However, as the pictures of the building were being shown live on Turkish television news channels, it suddenly shifted in the earth and teetered briefly before dramatically plunging onto the slope created by the mudslides.

Little was left of the building by the force of the impact other than rubble and a cloud of dust.

The building had already been evacuated and security forces had also cordoned off the area so no-one was hurt.

Reports said that the building fell into an empty area created by the planned construction of a hotel.

Beyoglu mayor Ahmet Misbah Demircan, who came to the s c e n e , v o w e d t h a t t h o s e r e s i d e n t s a ately receive housing, the state-run Anadolu news agency said.

He said the building dated back to 1994.

(THE GULF TIMES, July 25 2018, http://www.gulf-times.com/story/600643)

Istanbul horror as building collapses after land-slide

Torrential rains in Istanbul triggered a landslide on a con-struction site in the Sütlüce neighbourhood.

σ.σ. Από τις φωτογραφίες προκύπτει ότι μάλλον δεν είχε γίνει αντιστήριξη της παρειάς της εκσκαφής προς το καταστραφέν κτίριο, το οποίο κατέρρευσε προς την πλευρά της εκσκαφής.

https://www.express.co.uk/pictures/pics/21849/Istanbul-landslide-building-collapse-Turkey-rain

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ

«Βόμβα» από Γερμανούς επιστήμονες για τσουνάμι στον Θερμαϊκό

Πότε έγινε η πρώτη καταγραφή τσουνάμι στη χώρα μας – Οι περιγραφές του Ηρόδοτου που επιβεβαιώνουν σήμερα Γερμανοί επιστήμονες – «Ο Θερμαϊκός πρέπει να συμπεριληφθεί στη λίστα των περιοχών που ενδέχεται να υπάρξει τσουνάμι»

Την πρώτη καταγραφή τσουνάμι στην Ιστορία, που συνέβη στον Θερμαϊκό κόλπο το 479 π.Χ. και κατέστρεψε τον περσικό στόλο, σύμφωνα με τη γλαφυρή περιγραφή του Ηροδότου, μελετούν εδώ και χρόνια Γερμανοί γεωλόγοι στη Χαλκιδική και τα πρώτα συμπεράσματά τους φαίνεται πως επιβεβαιώνουν τον Έλληνα «πατέρα της Ιστορίας».

Ο καθηγητής του Πανεπιστημίου του Άαχεν, Κλάους Ράιχερτερ και συνεργάτες του βρέθηκαν ξανά πριν από λίγες ημέρες στη Χαλκιδική, αυτή τη φορά στο πλαίσιο διεθνούς συνεδρίου παλαιοσεισμολογίας, αρχαιοσεισμολογίας και ενεργού τεκτονικής και παρουσίασαν τα αποτελέσματα των έως σήμερα γεωσκοπήσεων και γεωτρήσεων που έκαναν στην περιοχή της Ποτίδαιας, καθώς και τα συμπεράσματα των μελετών.

Στην περιοχή αυτή συνέβη κατά τον Ηρόδοτο ένα ασυνήθιστο φαινόμενο, με απότομη υποχώρηση της παλίρροιας και τεράστια κύματα στη συνέχεια, που έπνιξαν το στόλο του Πέρση πολιορκητή της Ποτίδαιας Αρτάβαζου. Φαινόμενο, το οποίο ο αρχαίος Έλληνας ιστορικός απέδωσε στην οργή του Ποσειδώνα προς τον εισβολέα.

«Ο Ράιχερτερ και οι συνεργάτες του έκαναν μία σειρά από γεωλογικές έρευνες – γεωσκοπήσεις και γεωτρήσεις – στην ευρύτερη περιοχή και βρήκαν ενδείξεις που επιβεβαιώνουν το γεγονός που καταγράφει ο Ηρόδοτος το 479 π. Χ.» είπε στην εφημερίδα «Έθνος» ο καθηγητής Γεωλογίας του ΑΠΘ, Γιώργος Παυλίδης, προσθέτοντας: «Το γεωτρύπανο αποκάλυψε ιζήματα και θαλάσσιο υλικό – μικροοργανισμούς και πλαγκτόν – που έχει αποτεθεί ανάμεσα στα γεωλογικά στρώματα και τα χρονολόγησαν με άνθρακα. Βρήκαν πως στην περιοχή έχουν σημειωθεί γεωλογικές μεταβολές στην ιστορική περίοδο που περιγράφει ο Ηρόδοτος».

Ο Γερμανός καθηγητής έχει παρουσιάσει κάποια πρώτα συμπεράσματα των μελετών της ομάδας του σε διεθνές συνέδριο στις ΗΠΑ, επισημαίνοντας πως τα ευρήματα αυτά αποτελούν ενδείξεις ενός θαλάσσιου φαινομένου μεγάλης ισχύος στην περιοχή.

Είχε υποστηρίξει, μάλιστα, πως ο Θερμαϊκός πρέπει να ενταχθεί στον κατάλογο των περιοχών όπου ενδέχεται να υπάρξει τσουνάμι, με δεδομένο ότι πρόκειται για μία πυκνοκατοικημένη περιοχή με μεγάλη τουριστική ανάπτυξη.

Σημειώνεται πάντως πως 2.500 χρόνια μετά δεν έχει υπάρξει άλλη καταγραφή τσουνάμι στην ίδια περιοχή.

Αναφορικά με την αιτία που «γέννησε» το φαινόμενο, οι εκτιμήσεις των επιστημόνων διίστανται. «Κάποιοι το αποδίδουν σε ένα μεγάλο καταστροφικό σεισμό και κάποιοι άλλοι σε μεγάλη υποθαλάσσια κατολίσθηση στην Τάφρο του Βόρειου Αιγαίου» ανέφερε ο κ. Παυλίδης.

(Δημοσίευση: 4 Ιουλίου 2018)

Event deposits in the Eastern Thermaikos Gulf and Kassandra Peninsula (Northern Greece) and evidence of the 479 BC Herodotus - tsunami

Mathes-Schmidt, Margret, Papanikolaou, Ioannis, Reicherter, Klaus

Abstract: The world-wide first description of a tsunami and its effects in 479 BC were made by Herodotus. The wave hits the coast of Chalkidiki peninsula Greece where we investigated different areas from Angelochori down to Posidi (Kassandra peninsula) and the ruins of Mende. Ancient Mende was a quite important city in the classic Hellenistic period, already founded in the 12th cent. BC. However, the youngest parts of the city are situated close to the seaside (proasteion of the 6-5th cent. BC). Within the excavation of the proasteion, a high-energy layer has been encountered. Besides a vast amount of ceramics, the layer also contains shells of Acanthocardia sp. These have been dated as c. 2900 years BP by 14C, taking into account a reservoir effect of 400 years, which is a suitable candidate to the tsunami reported by Herodotus.

9th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology (PATA), 25 – 27 June 2018, Possidi, Greece

The Best Technologies for Predicting Earthquakes

A recent earthquake in Papua New Guinea shattered some of the country's most important gold mines. It also raised the question of what technologies are at miners' disposal when it comes to predicting quakes? **Ross Davies** reports

On 26 February, a 7.5 magnitude earthquake ripped through Papua New Guinea, claiming the lives of 160 people. At the time of writing, it remains the deadliest quake to strike this year.

Several mines that dot the pacific island – one of the world's most resource-rich countries – were among the areas hit. Ok Tedi Mining, which operates a large gold mine in the country's Enga province, reported significant infrastructural damage due to a landslide triggered by the quake.

The Porgera gold mine, also situated in Enga, sustained damage to its primary power generating facility; however, its Chinese operator, Zijin Mining Group Company, reported minimal damage beyond this, with no employees injured during the initial quake or subsequent aftershocks. And in the immediate aftermath, the mine was still able to operate on back-up power.

Things could have been a lot worse for Papua New Guinea's miners, but this incident highlights the risks of exploration in earthquake-prone regions. Furthermore, it poses the question: what difference can seismic monitoring technology make in the monitoring and prediction of earthquakes to help miners prepare for such events?

Tests on longwall coal mines

One technology that could make a difference is microseismic monitoring, which is able to record, analyse and interpret smaller quakes in the event of geological materials fracturing and failing. This can happen around underground excavations, such as longwall coal mines. The analysis of three component microseismic data can provide the location of the failure, as well as detailed information about the fracturing process's mechanisms and parameters.

The applied & environmental geophysics research group at Keele University has applied the technique to the monitoring and predictions of outbursts in longwall coal mines in both the UK and Australia.

"The nature of caving behaviour in the vicinity of longwall extraction can be critical to the financial success of a colliery," reads an extract on the group's official website. "Face support, interaction effects, optimum pillar design, subsidence at surface and control of water all depend critically on the distribution of fractures and stress induced by mining. Until now, there has been no method by which these effects could be observed."

Recently, the research group collaborated with UK company IMC Geophysics to create a new solution based on cementing seismic detectors, known as geophones, into a smaller number of in-mine boreholes to record simulated micro-earthquakes during mining operations.

According to the group, careful analysis of these recorded signals produced a map of the caving activity, "leading to increased understanding of all aspects of caving". This included the ability to observe the creation of caving features, highlight areas of abnormal caving, deduce optimal panel widths, and discover falling pillars.

Monitoring historical seismic data helps build intelligence about hot spot locations.

Is machine-learning the answer?

Artificial intelligence may also have a part to play. In 2016, a data mining competition organised by the University of Warsaw was held in Poland, where data scientists from across the world were invited to come up with new algorithms to predict earthquakes. More than 200 participants were provided with two datasets comprised of seismic activity records from 24 operational Polish coal mines. One was for training, consisting of 133,151 observations and the other for testing, made up of 3,860 observations.

With the goal of predicting seismic events up to eight hours in advance, prediction models were judged in their accuracy in respect to the area under ROC curve (AUC) metric – the standard classification analysis used to determine best prediction models. The eventual winner was Michał Tadeusiak, a big data science specialist with California-headquartered deepsense.io, which achieved an AUC of 0.939.

The results prompt a further question when it comes to AI as, with such large datasets, what constitutes a significant observation over a 24-hour period? According to Tadeusiak, there are 13 general features, which include the ID of the working site, as well as the overall energies derived from "bumps, tremors, distressing blasts and total seismic energy".

In India, researchers at the Sinhgad Institute of Technology and Science in Narhe, Pune, have also been examining how machine-based learning could help workers foresee and prepare for earthquakes in a coal mine setting.

In a paper from last year, the group proposed a prediction system based on datasets of attributes such as seismic energy, total energy, seismic bumps and shift, while suggesting various algorithms – such as neural networks and feature engineering – could also be used for training.

"The major challenge is to obtain accuracy in prediction with considerable time complexity," the paper states. "We can say that the mining-induced seismicity can be a mini model depicting earthquakes. Thus we can say that the proposed prediction system can be used for further earthquake prediction as well. The proposed software framework gives a user-friendly interface for coal miners that would either alert them or notify about dangers on basis of predictor system."

Finally, it seems that for now, while microseismic monitoring is a tool that has been deployed in the mining industry for some time, as means of ensuring greater operational safety, its main function for miners remains prevention rather than prediction.

(**mine**, Issue 70, July 2018, https://mine.nridigital.com/mine_jul18/the_best_technologies_for_predicting_earthquakes)

The 'death box' where Seattle earthquake researchers work

When the next major earthquake roils our region, University of Washington's civil engineers and seismic experts will not be safe.

That's because their building is vulnerable to earthquakes.

More Hall was built in 1946 before modern building codes were in place and, as a result, the building's concrete columns could explode like a fallen fine china during an earthquake.

"We make it worse," joked John Stanton, civil engineering professor. "We stack books up on the shelves so they can fall on us, as well."

More Hall on the University of Washington campus, left, and damage from the 7.1 earthquake that struck Mexico City, September 2017.

Stanton and his colleagues advise the Washington State Department of Transportation on how bridges will perform during earthquakes. They have won awards in the field of earthquake engineering. Their work obsesses over the best way to design buildings to withstand seismic forces.

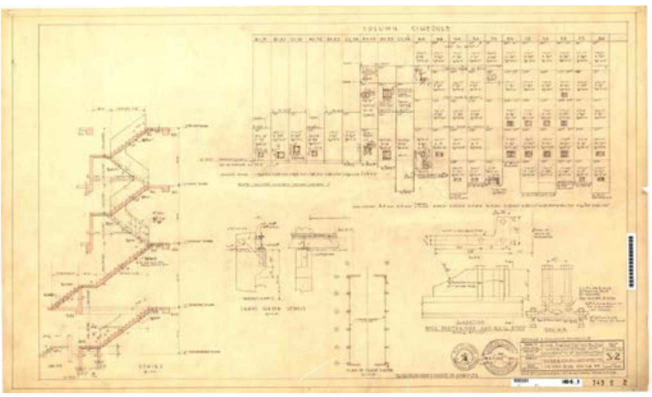
"The irony is absolutely there," Stanton said. "We would love to work in a safer place. That's a question of money and politics."

UW spokesperson Victor Balta downplayed the risk of More Hall and other buildings like it.

"It is true that More Hall was not built to today's seismic codes, but then again very few buildings were as codes continue to change," he said by email. The university's first priority, however, is dealing with shoring up its older brick buildings (known as unreinforced masonry) over the next six years.

"After we take care of all the unreinforced masonry, we will be able to move on to other seismic issues, many of which will involve very extensive renovations," Balta said.

Stanton gave a reporter a tour of More Hall, deciphering the building's cracks and warps as if with X-ray vision. (Actually, he's seen the architectural drawings.) They look like this:



Architectural drawings show details of the columns in More Hall, the 'scarily non-earthquake-proof' home of the University of Washington Department of Civil and Environmental Engineering.

All those numbers in the top right show the building's columns are "woefully unreinforced," according to Stanton.

Concrete columns in buildings up to modern code have a "bird cage of reinforcement" inside them, Stanton said. If you wrap a column in steel, it strengthens the concrete and keeps it together during an earthquake.

There is nowhere near enough steel latticework inside the columns of More Hall to make the building withstand a large earthquake, Stanton said. In contrast, wrapping a column in steel makes it ductile and bend like a paperclip during an earthquake.

That's why structural engineers call More Hall a "non-ductile concrete building."

"Death boxes" is the term preferred by international seismic engineering expert Kit Miyamoto.

Columns built before the mid-70s don't have much steel reinforcement, so they don't bend. Instead, they are known to explode.

"Yes, it does explode," he said. Miyamoto spoke to me from Los Angeles where he serves on the California Seismic Safety Commission. "It's a big, just sudden failure. It's not like you're going to see cracks happening. It just suddenly ruptures."

Last September many buildings like this collapsed in Mexico during a 7.1 earthquake.

A Mexican news site tweeted a video showing a beige, five story-apartment building that wobbles and then crumbles to the ground in a cloud of dust.

Sounds of "*Dios mio, dios mio, dios mio,*" Oh my god, oh my god, come from a woman watching.

In that earthquake, 44 buildings collapsed, 6,000 buildings were damaged, and close to 400 people died.

Everett-based structural engineer Dave Swanson visited Mexico to study the damage.

"When people look at a large massive concrete building they think, oh it's really strong, and it's going to be very reliable," Swanson said. "But I've witnessed earthquakes around the world throughout my career where buildings that you think are very reliable and strong actually aren't."

No one knows just how many buildings like this are in the Seattle area. But "there are a lot of them," Swanson said, certainly in the thousands.

Unreinforced masonry have gotten attention from local leaders, but the City of Seattle does not have a program to address vulnerable concrete buildings. The city says unreinforced masonry seem to suffer more in the earthquakes that have struck here.

Damage of 7.1 earthquake in Mexico, September 2017.

“They get damaged in smaller earthquakes," said Wendy Shark of the Seattle Department of Construction and Inspections. "Even in a small earthquake like Nisqually, two-thirds of the buildings that were initially red-tagged" — unsafe to occupy — "were URMs.”

Swanson is glad leaders are focusing on brick structures, but concrete ones need attention too, he said, as they are often large structures used by many people at the same time.

More Hall is not the only building on campus that needs seismic improvement. The University recently put out a call for bids to work on 11 unreinforced masonry buildings.

Hazard maps show the ground under the University of Washington’s Seattle campus is prone to liquefaction and will likely get a lot of shaking.

What would it take to bring More Hall up to current codes?

Joking, Stanton responds with dark humor: “A large bomb. Build a new one.”

(Anna Boiko-Weyrauch / KUOW, Jul 16, 2018, http://www.kuow.org/post/death-box-where-seattle-earthquake-researchers-work)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

We Are Now Living in a New Geologic Age, Experts Say

We are all in the midst of a new geological age, experts say.

This age, dubbed the Meghalayan, began 4,250 years ago when what was probably a planetwide drought struck Earth, according to the International Union of Geological Sciences (IUGS).

The Meghalayan is just one of three newly named ages, the IUGS said in an announcement released July 13. The other two ages are the Greenlandian (11,700 years to 8,326 years ago) and the Northgrippian (8,326 years to 4,250 years ago), the IUGS said.

Geologists have systematically divided up, and named, all of Earth's roughly 4.54-billion-year history. From the longest to shortest, these lengths of time are known as eons, eras, periods and ages. Currently, we're in the Phanerozoic eon, Cenozoic era, Quaternary period, Holocene epoch and (as mentioned) the Meghalayan age.

The IUGS shared an image of the newly named ages in a tweet. However, the group later issued a correction about the Meghalayan's length. (That age goes to the present, not to 1950 as the IUGS mistakenly tweeted.) You can see a larger version of the newly updated chart (also called the International Chronostratigraphic Chart) here.

The latest version of the International Chronostratigraphic Chart/Geologic Time Scale is now available! New #Holocene subdivisions: #Greenlandian (11,700 yr b2k) #Northgrippian (8326 yr b2k) #Meghalayan (4200 yr before 1950) https://t.co/IhvZHfHnWh#ChronostratigraphicChart208 pic.twitter.com/8Pf9Dnct7h — IUGS (@theIUGS) July 13, 2018.

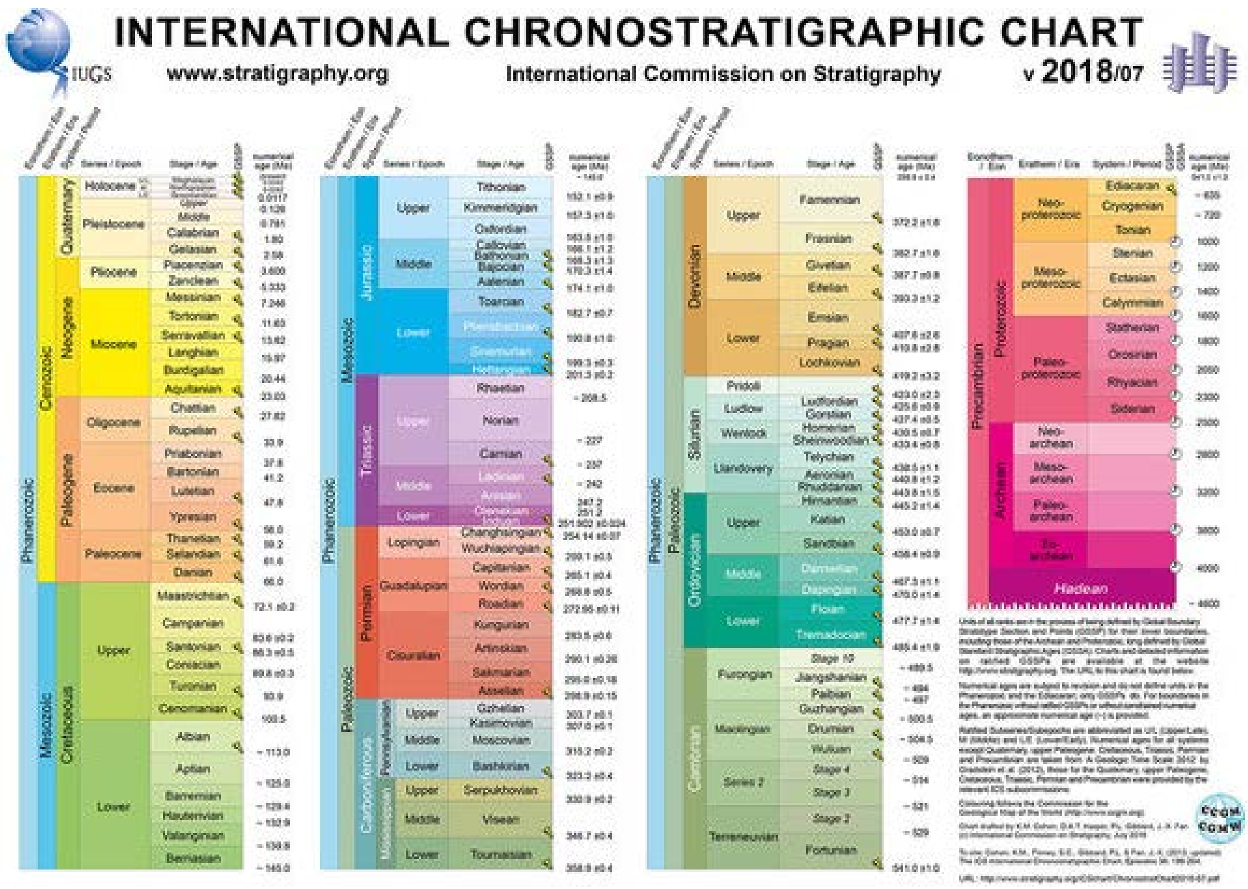
To determine the beginning time for each age, scientists looked at the unique chemical signatures found in rock samples from that time; each signature relates to a big climatic event, the IUGS said in a statement.

The Greenlandian, the oldest age of the Holocene (also known as the "lower Holocene"), began 11,700 years ago, as the Earth left the last ice age.

The Northgrippian (also known as the "middle Holocene") began 8,300 years ago, when Earth abruptly began cooling, likely because vast amounts of fresh water that came from Canada's melting glaciers poured into the North Atlantic and disrupted ocean currents, the BBC reported.

Meanwhile, the Meghalayan (also called the "upper Holocene") started 4,250 years ago, when a mega-drought devastated civilizations across the world, including those in Egypt, Greece, Syria, Palestine, Mesopotamia, the Indus Valley and the Yangtze River Valley, the BBC reported. This drought lasted 200 years and was likely prompted by shifts in ocean and atmospheric circulation.

Geologists chose the name "Meghalayan" as a nod to a rock sample they analyzed from Meghalaya, a northeastern state in India, whose name means "the abode of clouds" in Sanskrit. By analyzing a stalagmite growing on the ground of Mawmluh Cave, geologists found that each of the stalagmite layers had different levels of oxygen isotopes, or versions of oxygen with different numbers of neutrons. This change marked the weakening of monsoon conditions from that time, the BBC reported.



The International Chronostratigraphic Chart, including its newest ages: the Greenlandian, Northgrippian and Meghalayan.

The line on the Indian stalagmite shows where the Meghalayan Age began.

"The isotopic shift reflects a 20 [percent to] 30 percent decrease in monsoon rainfall," Mike Walker, a professor emeritus of quaternary science at the University of Wales in the United Kingdom, who led the naming of the ages, told the BBC.

Walker added that "the two most prominent shifts occur at about 4,300 and about 4,100 years before present, so the midpoint between the two would be 4,200 years before present."

Controversial age

Not everyone is satisfied with the new naming scheme for the ages. The Meghalayan was introduced only six years ago, in a 2012 study in the Journal of Quaternary Science.

Some geologists say that it's too soon to name the Holocene's ages, as it's not yet clear whether the climatic shifts were truly global, the BBC reported. Meanwhile, the name "Anthropocene epoch" has been floated as a geologic period marked by the dramatic impact that humans have had on Earth, but this name hasn't been formally submitted to the IUGS yet, the organization said on Twitter.

(Laura Geggel, Senior Writer / LIVESCIENCE, July 18, 2018, https://www.livescience.com/63103-meghalayan-age-within-holocene-named.html?utm_source=ls-newsletter&utm_medium=email&utm_campaign=20180719-ls)

Continental Drift: Theory & Definition

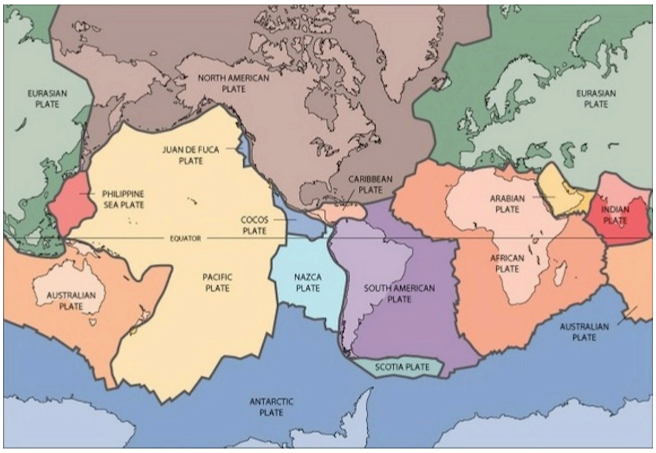
Continental drift was a theory that explained how continents shift position on Earth's surface. Set forth in 1912 by Alfred Wegener, a geophysicist and meteorologist, continental drift also explained why look-alike animal and plant fossils, and similar rock formations, are found on different continents.

The theory of continental drift

Wegener thought all the continents were once joined together in an "Urkontinent" before breaking up and drifting to their current positions. But geologists soundly denounced Wegener's theory of continental drift after he published the details in a 1915 book called "The Origin of Continents and Oceans." Part of the opposition was because Wegener didn't have a good model to explain how the continents moved apart.

Though most of Wegener's observations about fossils and rocks were correct, he was outlandishly wrong on a couple of key points. For instance, Wegener thought the continents might have plowed through the ocean crust like icebreakers smashing through ice.

"There's an irony that the key objection to continent drift was that there is no mechanism, and plate tectonics was accepted without a mechanism," to move the continents, said Henry Frankel, an emeritus professor at the University of Missouri-Kansas City and author of the four volume "The Continental Drift Controversy" (Cambridge University Press, 2012).



Tectonic plates of the Earth.

Although Wegener's "continental drift" theory was discarded, it did introduce the idea of moving continents to geoscience. And decades later, scientists would confirm some of Wegener's ideas, such as the past existence of a supercontinent joining all the world's landmasses as one. Pangaea was a supercontinent that formed roughly 200 to 250 million years ago, according to the U.S. Geological Survey (USGS) and was responsible for the fossil and rock clues that led Wegener to his theory.

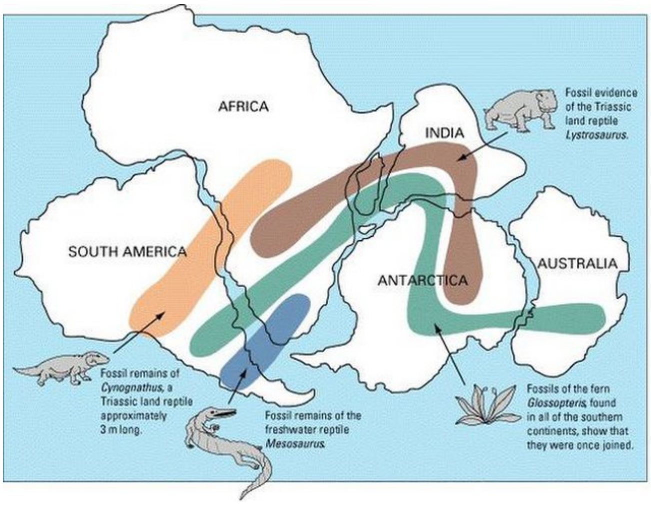
Evolving theories

When Wegener proposed continental drift, many geologists were contractionists. They thought Earth's incredible mountains were created because our planet was cooling and shrinking since its formation, Frankel said. And to account for the identical fossils discovered on continents such as South America and Africa, scientists invoked ancient land bridges, now vanished beneath the sea.

Researchers argued over the land bridges right up until the plate tectonics theory was developed, Frankel said. For instance, as geophysicists began to realize that continental rocks were too light to sink down to the ocean floor, prominent paleontologists instead suggested that the similarities between fossils had been overestimated, Frankel said.

Before the constriction theory, many thought that the world's formations were caused by a worldwide flood. This theory is called catastrophism, according to the USGS.

Plate tectonics is now the widely accepted theory that Earth's crust is fractured into rigid, moving plates. In the 1960s, scientists discovered the plate edges through magnetic surveys of the ocean floor and through the seismic listening networks built to monitor nuclear testing, according to Encyclopedia Britannica. Alternating patterns of magnetic anomalies on the ocean floor indicated seafloor spreading, where new plate material is born. Magnetic minerals aligned in ancient rocks on continents also showed that the continents have shifted relative to one another.



The theory of continental drift reconciled similar fossil plants and animals now found on widely separated continents. Gondwana is shown here.

Evidence for continental drift

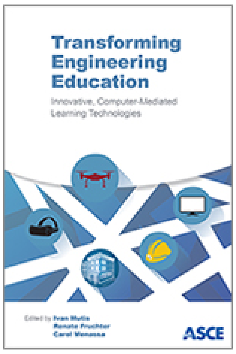
A map of the continents inspired Wegener's quest to explain Earth's geologic history. Trained as a meteorologist, he was intrigued by the interlocking fit of Africa's and South America's shorelines. Wegener then assembled an impressive amount of evidence to show that Earth's continents were once connected in a single supercontinent.

Wegener knew that fossil plants and animals such as mesosaurs, a freshwater reptile found only South America and Africa during the Permian period, could be found on many continents. He also matched up rocks on either side of the Atlantic Ocean like puzzle pieces. For example, the Appalachian Mountains (United States) and Caledonian Mountains (Scotland) fit together, as do the Karroo strata in South Africa and Santa Catarina rocks in Brazil.

In fact, plates moving together created the highest mountains in the world, the Himalayans, and the mountains are still growing due to the plates pushing together, even now, , according to National Geographic.

Despite his incredible evidence for continental drift, Wegener never lived to see his theory gain wider acceptance. He died in 1930 at age 50 just two days after his birthday while on a scientific expedition in Greenland, according to the University of Berkley.

(Becky Oskin, Contributing Writer and additional reporting by Alina Bradford, Live Science Contributor / LIVESCIENCE, December 19, 2017 https://www.livescience.com/37529-continental-drift.html?utm_source=ls-newsletter&utm_medium=email&utm_campaign=20180726-ls)



Transforming Engineering Education

Innovative Computer -Mediated Learning Technologies

Edited by Ivan Mutis, Renate Fruchter, and Carol C. Menassa

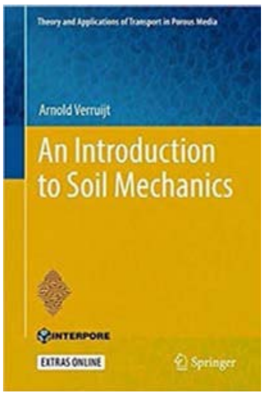
Transforming Engineering Education: Innovative Computer - Mediated Learning Technologies brings together 10 contributions on new approaches to research in the use of computer-mediated learning technologies in civil engineering education. The contributions present technology approaches that have made far-reaching improvements in learning outcomes and their alignment in the curriculum.

This book is divided into three areas: fundamental computing approaches in design and construction, virtual and augmented reality, and advances in BIM applications. Specific topics include spatial and temporal cognitive ability, construction-centric BIM education, strategic BIM coordination in model-based decision making, georeferenced augmented reality, mixed media mixed reality in the collaborative environment, CyberGRID as a virtual workspace, and a case study in virtual collaboration in an urban design project.

Researchers and educators in all areas of engineering education will find innovative and useful suggestions in this collection.

Sponsored by the Education Committee of the Computing Division of ASCE.

(ASCE, 2018)



An Introduction to Soil Mechanics (Theory and Applications of Transport in Porous Media)

Arnold Verruijt

This textbook offers a superb introduction to theoretical and practical soil mechanics. Special attention is given to the risks of failure in civil engineering, and themes covered include stresses in soils, groundwater flow, consolidation, testing of soils, and stability of slopes.

Readers will learn the major principles and methods of soil mechanics, and the most important methods of determining soil parameters both in the laboratory and in situ. The basic principles of applied mechanics, that are frequently used, are offered in the appendices. The author's considerable experience of teaching soil mechanics is evident in the many features of the book: it is packed with supportive color illustrations, helpful examples and references. Exercises with answers enable students to self-test their understanding and encourage them to explore further through additional online material. Numerous simple computer programs are provided online as Electronic Supplementary Material.

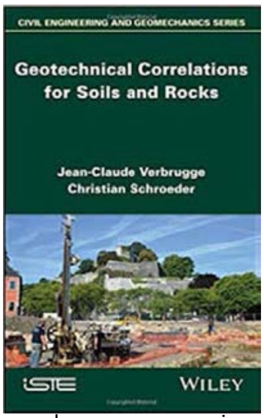
As a soil mechanics textbook, this volume is ideally suited to supporting undergraduate civil engineering students.

"I am really delighted that your book is now published. When I "discovered" your course a few years ago, I was elated to have finally found a book that immediately resonated with me. Your approach to teaching soil mechanics is precise, rigorous, clear, concise, or in other words "crisp." My colleagues who share the teaching of Soil Mechanics 1 and 2 (each course is taught every semester) at the UMN have also adopted your book."

Emmanuel Detournay

Professor at Dept. of Civil, Environmental, and Geo-Engineering, University of Minnesota, USA

(Springer, 1st ed. 2018 edition July 26, 2017)

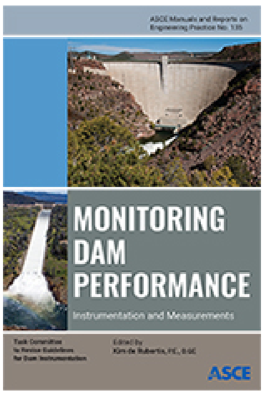


Geotechnical Correlations for Soils and Rocks 1st Edition

Jean -Claude Verbrugge and Christian Schroeder

The modelling tools for soils and rocks require more and more specific parameters not always available from the standard or usual survey campaigns, this generally for reasons of delay or costs. The use of correlations to solve the gap between available parameters and the required ones is a common practice. Many of them exist but are spread throughout numerous papers or books. The aim of this formulary is to provide a large synthesis of the existing correlations accumulated by the authors during more than 40 years academic and consulting careers.

(Wiley-ISTE; 1st edition July 24, 2018)



Monitoring Dam Performance

Instrumentation and Measurements

Task Committee to Revise Guidelines for Dam Instrumentation; edited by Kim de Rubertis, P.E., D.GE

Geotechnical Special Publications (GSP) GSP 135

Prepared by the Task Committee to Revise Guidelines for Dam Instrumentation of the Committee on Water Power of the Energy Division of ASCE.

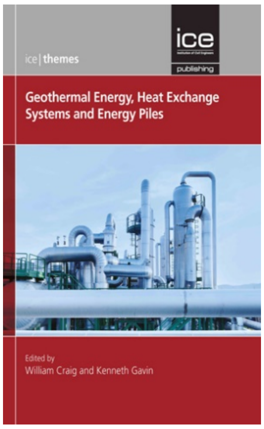
Monitoring Dam Performance: Instrumentation and Measurements presents the fundamentals and current state of practice of instrumented measurements for monitoring dam performance. Dam performance monitoring is a balance of visual surveillance and instrumental measurements to accurately understand how well a dam is performing. Mechanical, electromechanical, and electronic instruments are used to measure geotechnical, structural, hydraulic, or geohydrologic dam performance indicators that are not observable by visual surveillance.

Performance monitoring as part of a comprehensive dam safety program is a powerful tool for identifying and managing the risk of failure associated with a dam. Instrumented monitoring produces quantitative data regarding foundation, reservoir, tailwater, and precipitation conditions surrounding and within the dam. Instrumented monitoring can provide long-term records of data, allowing for detection of time or load-dependent trends in a dam's performance. MOP 135 delves into embankment, concrete, and other types of dams. It also examines their possible vulnerabilities, as well as explores how their potential modes of failure lead to asking performance questions that instrumented measurements can help monitor. This manual of practice covers

- recognizing vulnerabilities affecting dam performance;
- identifying performance indicators;
- understanding means and methods of measuring performance indicators;
- planning and implementing a monitoring program;
- acquiring, managing, evaluating, and presenting data; and
- making decisions and taking action on the basis of monitoring results.

MOP 135 is a valuable resource for members of the global dam community, including dam owners, engineers, and regulators.

(ASCE, 2018)



Geothermal Energy, Heat Exchange Systems and Energy Piles (ICE Themes)

Edited by William Craig and Kenneth Gavin

The ICE Themes series showcases cutting edge research and practical guidance in all branches of civil engineering. Each title focuses on a key issue or challenge in civil engineering, and includes research from the industry's finest thinkers and influencers published through the ICE Publishing programme. Themes in the series include climate change resilience, advances in construction management, developments in renewable energy, and innovations in construction materials plus many more.

Geothermal Energy, Heat Exchange Systems and Energy Piles (ICE Themes) focuses on topics from high temperature geothermal energy extraction, to lower temperature situations at ground surface and shallow depths. Providing broad international coverage, the chapters encompass field observations on sites in several countries as well as computational and laboratory studies. Ground conditions vary from hard rock to chalk, loess to London Clay.

Key features of this book include:

- international case histories on geothermal energy extraction
- coverage of geothermal resource exploration, characterisation and evaluation
- design and assessment of energy piles.

This book, which has been edited by two leading experts in the field, is an ideal resource for engineers and researchers seeking an overview of the latest research in this exciting area.

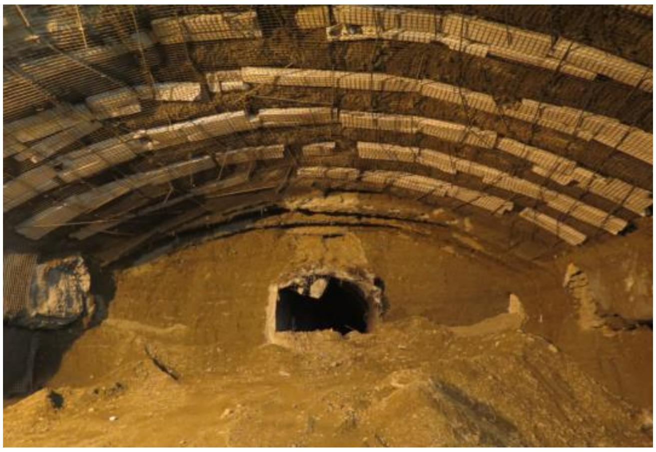
(ICE Bookshop, 05 July 2018)

ISSMGE International Journal of Geoengineering Case Histories

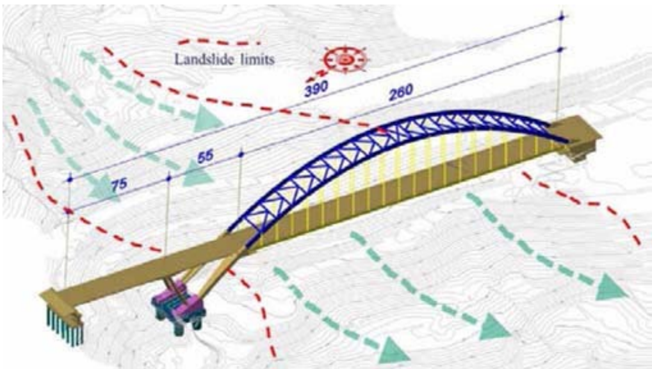
Vol. 4, Issue #3

ISSMGE

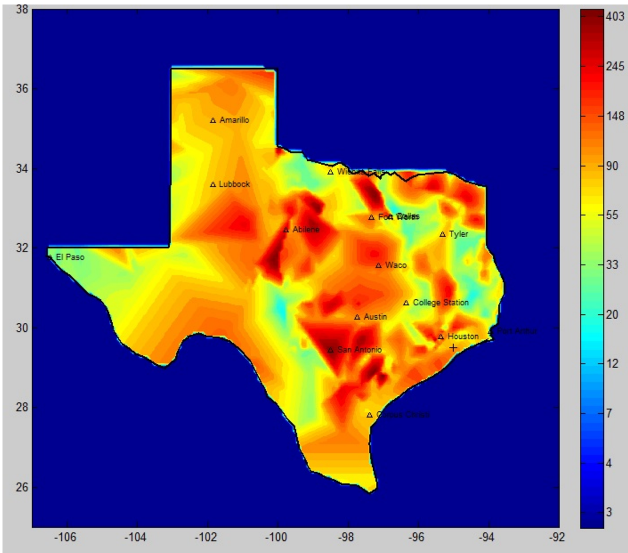
Behnam Eslami, Aliakbar Golshani "Performance of CAPS Method Considering its Interaction with Adjacent Structures - The Q7 Station of Tehran Metro Line 7", p.147-161



Konstantinos Seferoglou, Isabella Vassilopoulou, Fragiskos Chrysohoidis "Geotechnical and Structural Challenges over an Active Landslide", p. 162-184



Jean-Louis Briaud, Inwoo Jung, Anand Govindasamy, Dongkyun Kim, Jaehyeon Lee "The Observation Method for Bridge Scour: Case Histories", p.113-133



Cor Zwanenburg, Norma Patricia López-A c o s t a , m T o ment, Alessandro Tarantino, Annarita Pozzato, Alexandre Pinto "Lessons Learned from Dike Failures in Recent e c - ades", p.203-229

ITA@news

Message from Tarcisio Celestino, ITA President

World Tunnel Congress 2018 in Dubai: The Middle East Consolidated its Position as Powerful Emergent Market

Photos of WTC 2018 are available

68 Entries for the ITA Tunnelling Awards 2018

Guidelines for Good Working Practice in High Pressure Compressed Air Version 2018

Guidelines for The Provision of Refuge Chambers in T u n - nels Under Construction

Guideline for Good Practice of Fibre Reinforced Precast Segment - Vol. 2 : Production Aspects

ITACUS had a great time at the Think Deep UK Summer Event and engaged in inspiring conversations to launch new initiatives

Find the proceedings of PIARC's International Seminars on www.piarc.org

The orld oad Association (PIA C) aims to encoura e in-ternational cooperation in the field of road and road transport and to "**play a leading role in knowledge exchange on policies and practices in an integrated and sustainable transport context** . To do so, it draws on its broad mem-bership base (121 national governments) and geographical diversity.

In addition to the congresses that it organizes every four years (World Road Congress and International Winter Road Con ress) and which constitute leadin international plat-forms for dissemination of its productions and sharing of knowledge, PIARC also organizes international seminars and workshops. These are organized with the assistance of PIARC Technical Committees and Task Forces, which bring together more than 1,200 experts. During the 2016-2019 cycle, more than 20 seminars have already been organized and many more are planned.

The pro ram and proceedin s o PIA C international semi-nars are posted online after each seminar. You can consult them on PIARC's website. *Further information*

ΕΚΤΕΛΕΣΤΙΚΗ ΕΠΙΤΡΟΠΗ ΕΕΕΕΓΜ (2015 – 2018)

Πρόεδρος	:	Γεώργιος ΓΚΑΖΕΤΑΣ, Δρ. Πολιτικός Μηχανικός, Καθηγητής Ε.Μ.Π. president@hssmge.gr, gazetas@ath.forthnet.gr
Α' Αντιπρόεδρος	:	Παναγιώτης ΒΕΤΤΑΣ, Πολιτικός Μηχανικός, ΟΜΙΛΟΣ ΤΕΧΝΙΚΩΝ ΜΕΛΕΤΩΝ Α.Ε. otmate@otenet.gr
Β' Αντιπρόεδρος	:	Μιχάλης ΠΑΧΑΚΗΣ, Πολιτικός Μηχανικός mpax46@otenet.gr
Γενικός Γραμματέας	:	Μιχάλης ΜΠΑΡΔΑΝΗΣ, Πολιτικός Μηχανικός, ΕΔΑΦΟΣ ΣΥΜΒΟΥΛΟΙ ΜΗΧΑΝΙΚΟΙ Α.Ε. mbardanis@edafos.gr, lab@edafos.gr
Ταμίας	:	Γιώργος ΝΤΟΥΛΗΣ, Πολιτικός Μηχανικός, ΕΔΑΦΟΜΗΧΑΝΙΚΗ Α.Ε.- ΓΕΩΤΕΧΝΙΚΕΣ ΜΕΛΕΤΕΣ Α.Ε. gdoulis@edafomichaniki.gr
Έφορος	:	Γιώργος ΜΠΕΛΟΚΑΣ, Δρ. Πολιτικός Μηχανικός, Επίκουρος Καθηγητής ΤΕΙ Αθήνας gbelokas@teiath.gr, gbelokas@gmail.com
Μέλη	:	Ανδρέας ΑΝΑΓΝΩΣΤΟΠΟΥΛΟΣ, Δρ. Πολιτικός Μηχανικός, Ομότιμος Καθηγητής ΕΜΠ aanagn@central.ntua.gr
		Βάλια ΞΕΝΑΚΗ, Δρ. Πολιτικός Μηχανικός, ΕΔΑΦΟΜΗΧΑΝΙΚΗ Α.Ε. vxenaki@edafomichaniki.gr
		Μαρίνα ΠΑΝΤΑΖΙΔΟΥ, Δρ. Πολιτικός Μηχανικός, Αναπληρώτρια Καθηγήτρια Ε.Μ.Π. mpanta@central.ntua.gr
Αναπληρωματικό Μέλος	:	Κωνσταντίνος ΙΩΑΝΝΙΔΗΣ, Πολιτικός Μηχανικός, ΕΔΑΦΟΜΗΧΑΝΙΚΗ Α.Ε. kioannidis@edafomichaniki.gr
Εκδότης	:	Χρήστος ΤΣΑΤΣΑΝΙΦΟΣ, Δρ. Πολιτικός Μηχανικός, ΠΑΝΓΑΙΑ ΣΥΜΒΟΥΛΟΙ ΜΗΧΑΝΙΚΟΙ Ε.Π.Ε. editor@hssmge.gr, ctsatsanifos@pangaea.gr

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

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

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

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