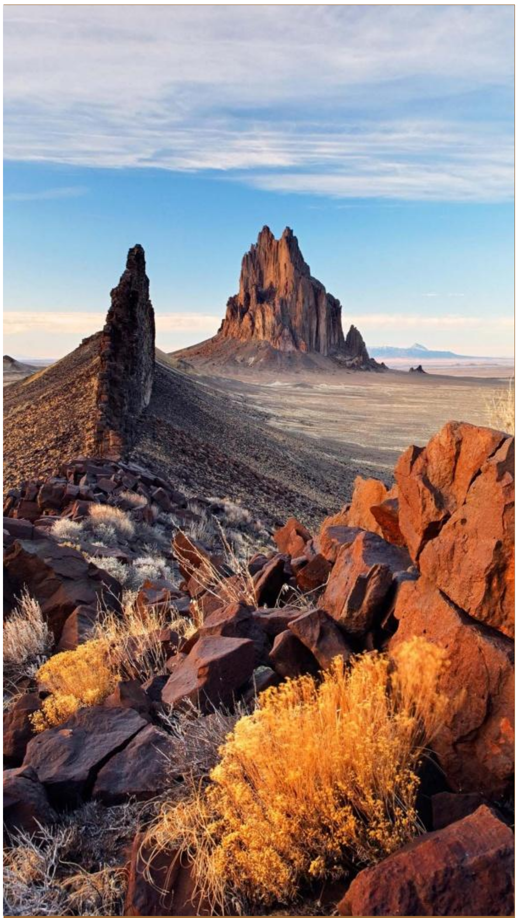

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The benefits of including geotechnical data in BIM

Building Information Modelling (BIM) is becoming increasingly common around the world on building and civil engineering projects, but what are the benefits to geotechnical engineers and where is the technology in meeting those benefits? Here's a look at the issues.

BIM: A Definition

The U.S. National Building Information Model Standard Project Committee defines Building Information Modelling (BIM) as: "… *a digital representation of physical and functional characteristics of a facility. BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*"

While BIM is typically associated with dynamic 3-D design models (i.e., those that change over time by continual updating with new data during the project), it is not a product. BIM is a method of working and collaborating throughout the entire lifespan of a project, from initial feasibility; through design and construction; and into the operational and maintenance phases

At its most basic, BIM could be considered simply as a file-based collaboration and library management system of 3-D data — a way for the project team to share and store information (from architectural plans to site investigation data).

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Of course, standard version control is essential to ensure only owners and permitted users of data are able to carry out updates.

Another level of BIM is to use the data from project team members to produce 3-D models of the proposed design to create a digital model (Figure 1). This allows the team and other stakeholders (the client and investors) to visualize and analyze the virtual prototype and show how the different components of a design fit and interact with one another. Additionally, terms like "BIM 4-D" and "BIM 5-D" are often used. 4-D relates to the ability to model changes over time, while 5-D refers to inclusion of cost and quantities.

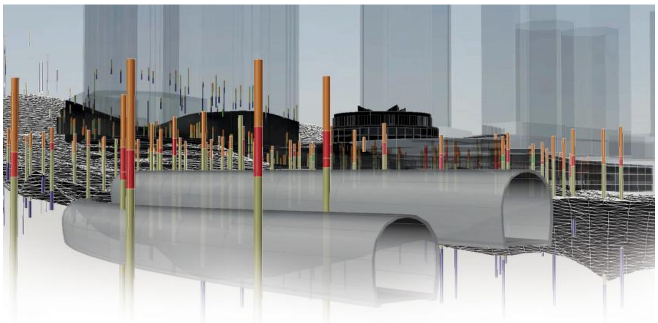

Figure 1. Building Information Modelling enables visualisation of geotechnical data, allowing creation of 3D models of the proposed design.

In theory, a geotechnical engineer can use 5-D BIM principles to design ground investigations, create 3-D ground models, design earthworks and foundations, calculate and model quantities, track construction phases and costs over the course of the project, and also plan asset management strategies. BIM certainly enables better decision making and reduces risk, encouraging true collaboration, which is also essential to get the full benefits of the technology – faster and more economical projects. BIM also has a positive effect on environmental impact. For example, balancing cut and fill is easier and estimates of amount of materials needed are more accurate, reducing waste and lorry movements.

The Benefits of BIM to Geotechnics

While the use of BIM has grown massively in recent years, it often seems to start from the ground up, with the subsurface considered as a homogenous substance. This implies there is no risk in the ground, which is clearly untrue. Of course, there are a host of benefits to including geotechnics in BIM and applying its principles to geotechnical data management. For example, BIM allows all design options to be considered and refined from the outset by minimizing geotechnical risk during construction and enabling cost-effective repairs and maintenance of assets throughout the project's lifetime (Figure 2).

In the U.K., BIM has been used for geotechnical applications on a wide range of projects. During the feasibility stage of the High Speed 2 rail project - a new north-south route stretching from London to the northwest of England - data from desk studies, geographic information systems, and sources such as the U.K. Coal Authority was fed into the project BIM, providing a comprehensive view of mining infrastructure that could affect the final alignment.

The consultant has also used BIM on highway projects, optimizing the design of 850,000 m^3 of cut and fill earthworks on a road in northeast England. The 3-D modelling environment was used to design ground investigations, earthworks, borrow pits, formation levels, and foundations for numerous overbridges, making them more efficient and cost-effective.

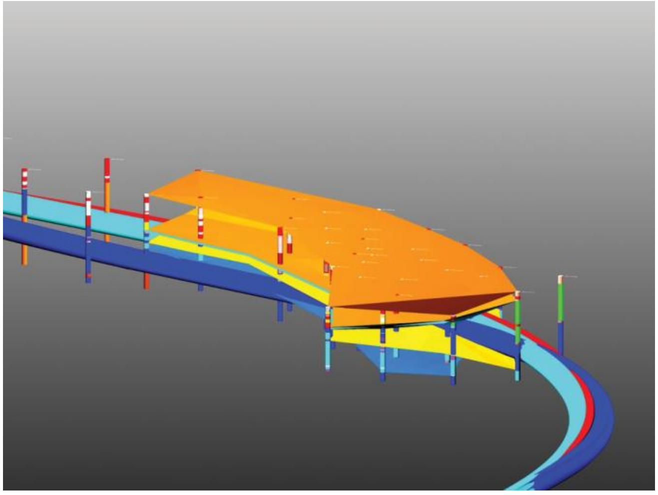

Figure 2. Brisbane: By using geotechnical BIM, the ground model and tunnel alignment could be altered quickly and easily as data was gathered.

BIM was a critical aspect of assessing the viability of Science Central, a major mixed use development in Newcastle, U.K. It created a ground model using ground investigation data and local knowledge to enable the geometry and volume of coal that would have to be mined as part of the ground enabling works, as well as modelling predicted settlement and outline designs for mitigation.

By including geotechnical and site investigation data in the BIM process and in CAD drawings, information can be visualized rapidly. This creates geotechnical models, 3-D borehole layouts, dynamic geotechnical profiles, and geological surfaces and sections in seconds rather than hours. More significantly, the team will come to recognize how critical it is to have high-quality geotechnical information available when creating an accurate BIM model. The BIM process will therefore reinforce two key messages: That early and thorough site investigation can reduce project risk and that geotechnical engineering is an integral part of the entire project.

Data Sharing

Using BIM also encourages collaboration within the geotechnical team (i.e., contractors and consultants). Data sharing and central data management can drive large improvements in efficiency and quality. Geotechnical data management systems are able to export factual and interpreted data and can be used to create borehole logs, reports, charts, and interpretations of data within seconds, allowing geotechnical data to be updated and managed throughout the lifetime of a project.

Sharing of geotechnical data digitally is nothing new. The U.K. Association of Geotechnical and Geoenvironmental Specialists (AGS) format has been around since 1989 and is widely used, and often specified by clients around the world. However, there are limitations. Currently, the AGS data format cannot be used to transfer interpreted data such as ground models, although this is being addressed by the AGS in its next update.

However, according to a recent survey, many geotechnical teams are reluctant to supply digital data rather than written reports with the wider project team. While this is a potential barrier to geotechnical data being incorporated into BIM, geotechnical practitioners are concerned by the possibility of interpretative data being misused by others. Better data sharing should actually lead to a more complete understanding of the project elements, resulting in more informed decision making. If collaboration is improved, the risk of interpreted data being misused will also be lower.

An example of the philosophy of sharing digital data as part of a collaboration information management system is the Highways Agency Geotechnical Data Management System (HAGDMS).

HAGDMS was introduced in the early 2000s. It is a web-based system for the complete management of geotechnical assets on the England trunk road network for the Highways England. Using many of the principles involved in BIM, it is designed for the whole life of a project – collating all data in one place to allow informed decisions to be made. It covers all aspects of geotechnical and drainage information, including borehole data, scanned report archives, earthwork condition reports, and maintenance requirements, and drainage network connections for the whole road network in England.

The data management system has been successfully rolled out to a community of more than 1,000 users in over 300 national offices by Mott Macdonald in association with Keynetix. It has now become one of the largest geo-referenced geotechnical and drainage asset management tools in the world, with 220,000 observations on over 45,000 geotechnical assets and more than a million drainage assets. The system provides access to nearly 200 mapping layers, 114,000 photographs and sketches, 20,000 geo-referenced files, and 15,000 downloadable reports.

HAGDMS is a vital source of geotechnical data for BIM projects. Although the web viewer does not include 3-D visualization, the AGS data downloadable from the system can be easily viewed in a 3-D environment using desktop applications. This extensive data set allows geotechnical professionals fast access to a comprehensive model of the information available at any particular site.

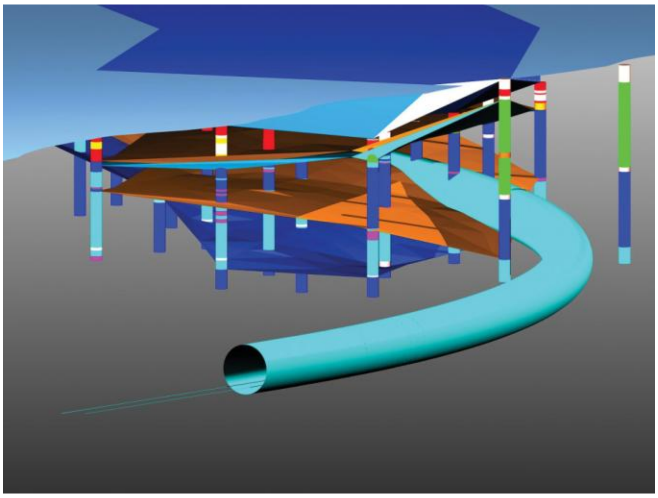

Figure 3. Brisbane: The 3-D model aided engineering design and helped non-technical staff better visualize the project.

Ground Investigation Optimization

Having access to full project information allows the geotechnical team to optimize ground investigations. Being able to view the latest proposed designs during the desk study phase can assist in identifying where information is required and can help direct work on site, in terms of sampling and in situ and laboratory testing.

It is very difficult, if not impossible, to change the focus of an investigation without commissioning additional work. Having access to field data in real time and incorporating it into BIM almost immediately gives the opportunity to refocus sampling and testing mid-investigation. This should deliver more useful data, hence reducing risk and potentially saving money in the long term. This certainly proved to be the case on a ground investigation for the design of a proposed tunnel in Brisbane, Australia.

For this tunnel project, "the aim was to create a 3-D model to aid engineering design and also to help non-technical staff better visualize the project," explains CMW Geosciences Principal Geotechnical Engineer Craig Butterworth. "Of particular importance was the ability to develop a 'live' 3-D ground model to help understand the nature of the geology along the proposed route while site investigation was underway. Due to time and cost pressures, the team wanted to gain the maximum benefit from site investigation and ensure there were no significant gaps or unknowns in the ground model derived from the boreholes (Figure 3)."

Data was captured digitally and transferred to CMW promptly after each borehole was completed. Then CMW transferred the data into a 3-D model using the HoleBASE SI Extension for AutoCAD Civil 3-D. "The 3-D model was then sent back to the project geologists within a 3-D visual viewer. As data was collected in electronic format, the process was much faster and avoided data entry errors," Butterworth explains. "The live model helped the team visualize the ground model in three dimensions rather than using traditional 2-D sections (Figure 4). By using geotechnical BIM, the tunnel alignment could be altered quickly as the ground model was updated with new data.

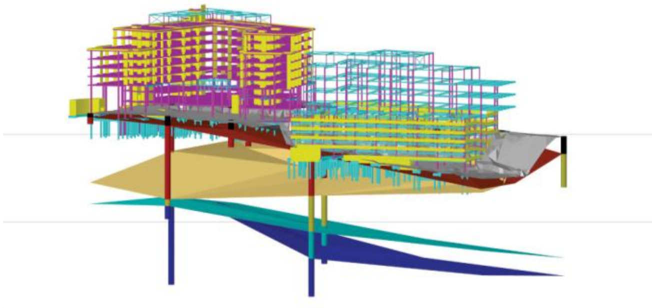

Figure 4. Incorporating geotechnical data in BIM enables design optioneering and refinement; minimises geotechnical risk, and enables repair and maintenance of assets throughout the project's lifetime.

What's Next for BIM?

We have just begun a two-year research project in conjunction with the British Geological Survey (BGS). The project aims to advance the use of geotechnical BIM by creating a cloud-based database of U.K. geological and geotechnical data, along with 3-D interpretative ground models.

The *BIM for the Subsurface* project is funded by Innovate UK (a public body supporting business innovation, sponsored by the U.K. Government's Department for Business, Innovation and Skills) under its Digitising the Construction Industry initiative. As well as Keynetix and BGS, the research team includes Autodesk and engineering consultant Atkins.

The project aims to tackle one of the biggest barriers to geotechnical BIM (certainly in the U.K.) — the limited availability of high-quality geotechnical data which is stored mainly in privately-owned project archives. BGS, which has been at the forefront of geological data management, visualization, and delivery in the U.K. for some time, believes research will lead to a step-change in how it delivers its data and models to the geotechnical engineering and construction sectors.

The work will build upon an increasingly open and accessible wealth of geoscience data in the U.K. It is hoped that by giving public access to better data, along with 3-D interpretative models, practitioners will be encouraged to share project data, and the use of geotechnical data in BIM will rise.

In fact, as the use of BIM in civil engineering projects grows around the world, by extension, its use in geotechnics should also grow. Currently, BIM is aimed primarily at projects where the total cost is in the tens of millions of dollars; however, it is anticipated that some countries will begin using this approach for smaller projects. For example, the U.K. government stated in its May 2011 Government Construction Strategy that all public projects will "require fully collaborative 3-D BIM (with all project and asset information, documentation, and data being electronic) as a minimum by 2016." The private sector is sure to follow once it sees the benefits.

With unforeseen ground conditions continuing to be a major cause of delays and construction program overruns on projects around the world, it is crucial that geotechnical professionals drive the adoption of BIM. By gathering and sharing geological and geotechnical data with the rest of the project team, site investigations will be more focused and ground risk reduced, saving time and money. An even bigger benefit, perhaps, is that BIM can give geotechnical teams the opportunity to share their visions and concerns for the ground conditions early in the design, as well as to provide input throughout the project, including the operation and maintenance phases and extending into decommissioning, if need be.

Moreover, the geotechnical sector continually strives to improve its standing, and, for this reason alone, it should be embracing BIM and helping to improve the way geotechnical data is managed and shared in the future.

Gary Morin is the technical director and co-founder of Keynetix, located in Redditch, Worcestershire, U.K. A civil engineer by training, Gary has more than 27 years of experience developing and supporting a range of software, and specializes in spatial information management. Gary heads up Keynetix's design and support services for its products that manage geotechnical data in the BIM process. He can be reached at *gary.morin@keynetix.com.*

Geostrata, November / December 2015, pp. 56-62

Για περισσότερες βασικές λεπτομέρειες για το τι είναι και τι προσφέρει το BIM δείτε το άρθρο στην επόμενη σελίδα.

BIM for all - dummies or not!

Anna Winstanley and Nigel Fraser

What is BIM?

A quick internet search brings to mind an old tale...

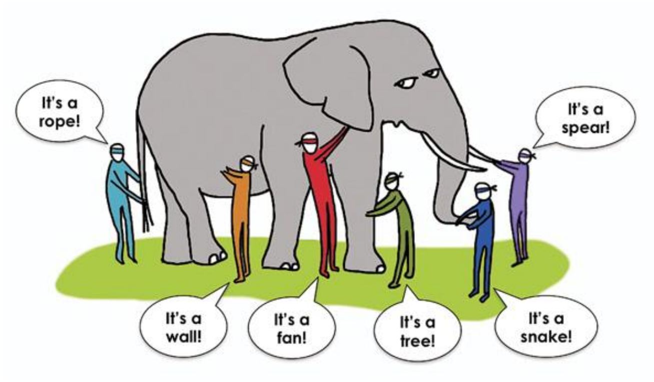

Figure 1 - If you cannot see the whole picture...

BIM seems to be something different depending on the point of view. The various participants in the design, construction and management of the asset (e.g. building or infrastructure), may experience BIM in different ways.

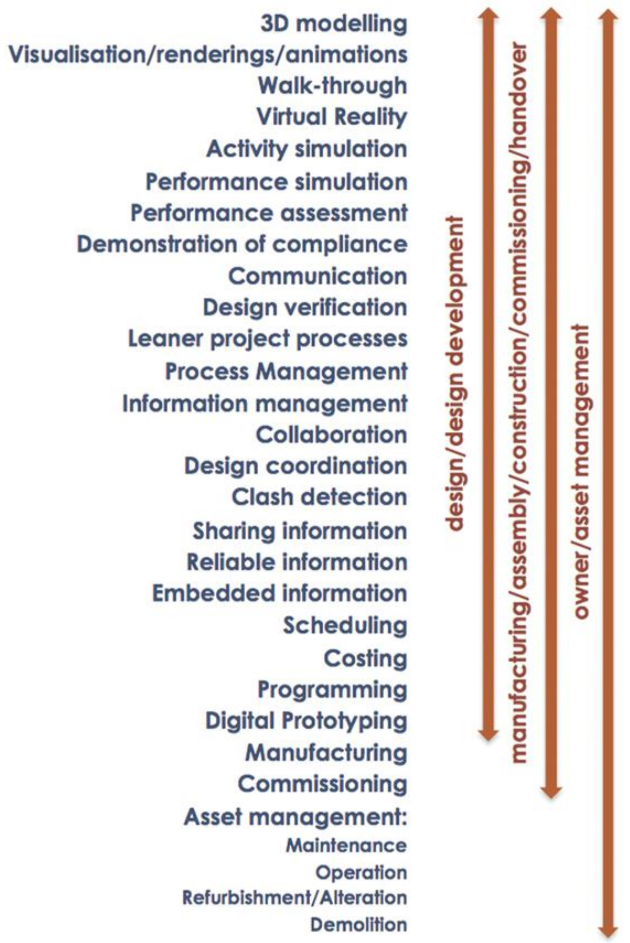

Figure 2 - What is BIM?

The list in Figure 2 includes both 'what' can be done with the tools and 'what for', all of which can be applicable when describing BIM. Some of these may not be known across the industry because they are not relevant to every party in a project, but these are not new!

So what is new about BIM?

Starting from the basics, in the context of a project, BIM is about creating a model of the asset that represents its physical characteristics, its performance, the way it is to be constructed and anything else of use to those involved in designing, building and operating the asset.

Figure 3 - A card model

A BIM model is not simply a 3D CAD model, i.e. digital equivalent of a card model! 3D CAD models are not new, but in most cases they represent only the visual aspects of the building.

A BIM model is something else. Technology that has been used for some time by other industries, e.g. cinema, computer games, and some manufacturing, is now accessible to the construction industry and to building owners.

With more powerful computers and access to the databases behind the graphics, it is possible to add non-graphic information about the components (BIM objects) in the digital model.

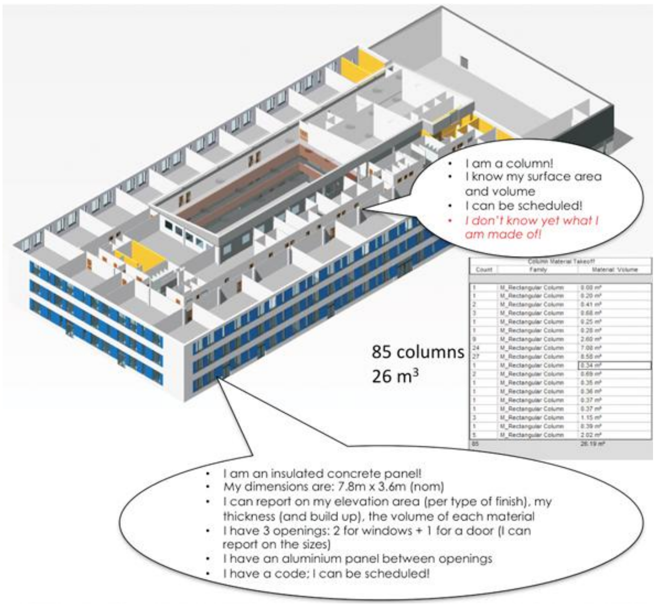

Figure 4 - A BIM model is rich in information but should not contain too much too soon

A great deal of information can be added to a model. It can then be sent to another party and they can access the information. It sounds simple, but there are a few points to be considered.

First, information has to be added by the party creating the model before the receiving party can see it. For example, very early in the design process the architect may add doors to the design model, but before the fire strategy is developed, the fire rating may not be known so will not be included in the door component (BIM object). In this case, if the cost planner receives the model, the number of doors and their sizes can be scheduled out, but there will be no information about whether these need to be fire rated, which could affect the costs.

To avoid frustration the team should start the project by agreeing what information will be added to the model and when. Each party can then plan their work knowing what and when to provide and to expect information through the model. This should involve all parties and requires collaboration at the project planning stage.

Second, the party receiving the model may want to manipulate the information contained therein using a different computer application from the one used to create the model. For example, the environmental engineer may want to analyze the architectural model for compliance with Part L of the Building Regulations. For that, the architectural model may need to be 'imported' into the analysis software. For this to work the model may have to be 'translated' into a format that is understood by the analysis software.

Similarly, if the contractor wants to use the consultants' design model to plan his/her site activities, he/she may want to link it to or import into his/her own sequence planning application. If for example the in situ concrete slab was modeled as one element, but is going to be constructed in phases, it will have to be split. Besides the digital format compatibility issues, the modelling criteria need to be planned.

Work by most major software developers is progressing, to help the exchange of data between applications, through a common format. It is hoped that soon the users won't have to be concerned with the technicalities involved. It just needs to work!

Figure 5 - It should be as simple as using a tablet!

Third, the model has to 'make sense' to the party receiving it. In Figure 5, the architect may have built the external walls in the model from a series of components classified as 'panels', while the engineer's software may only understand components classified as 'walls'.

Work is progressing, by industry and professional organizations, to define/agree common classifications. These can then be built into the relevant applications and be embedded in project templates, processes and protocols. Again, this should help to avoid having to deal with this individually.

In the meantime and to avoid frustration, the project team should start the project by agreeing what software each party is planning to use for what and at what stage(s). They can try the envisaged 'translations' in advance to be confident this will not cause problems later on. Similarly, modelling principles can be agreed to avoid elements not being suitable for the envisaged use because of the way they were created. This should also involve all parties and should take place at the project planning stage.

Planning the processes and aligning the information exchange with the design and procurement strategies is a task that requires professional experience as well as the knowledge about the tools and technologies to be adopted.

This should not be delegated to the BIM management and co-ordination function because the designers need to align their work plans among themselves, within the procurement strategy and with the BIM processes. This is about 'planning the thinking' and can only be done by those involved in the multi-disciplinary design development!

How to deliver the total BIM process with all its benefits for less than the sum of the parts

Each organization involved in the process needs to get their strategy in place to align their internal processes with the project processes. For the organization, it is this alignment that will avoid duplication, enable efficiencies and realize the benefits from BIM adoption. At the project level, the alignment of all parties is fundamental and for this, each party needs to be prepared.

How to engage with projects? How to align the internal processes with project processes?

Lean BIM Strategies have been developing strategies for clients, consultants, suppliers and manufacturers, to develop BIM enabled internal processes and to support simple and efficient interfaces with projects. They have worked with CIRIA to prepare two training workshops that will help people to understand how their organization can get the most out of BIM adoption on a project.

Since the last workshop, the content has been updated to engage a more experienced group of participants, although you won't feel left out if you are new to BIM. Clients, consultants, contractors, suppliers and manufacturers were creating buildings together before BIM and your experience and expertise in designing, constructing and operating an asset are needed for the successful implementation of BIM on projects!

Getting on with the project

The benefits of BIM adoption depend on all parties being able to engage and collaborate in a well-informed way. In the BIM world all participants depend on each other to succeed!

There may be a lot of focus on technology, but BIM is also about people and processes. People need to understand the opportunities offered by technology and make choices about how to use it. People need to review their old processes and change these to make the most of new technology. Then adopting new processes, people need to use technology to do more with less effort and in less time, not simply do the same as before more efficiently… Technology and good processes can improve collaboration… but only if the people involved want to collaborate!

(Anna Winstanley and Nigel Fraser / NBS, 01 August 2013, https://www.thenbs.com/knowledge/bim-for-all-dummies-or-not)

ΑΡΘΡΑ

MSE Wall Failures vis-à-vis the Lack of Geotechnical Filters

Dr. Robert M. Koerner

Since 2001, the **Geosynthetic Institute** has accumulated data on failures of geosynthetic-reinforced mechanically stabilized earth (MSE) retaining walls. Our MSE wall failures database presently has 301 cases, of which 191 (63%) have been caused in whole or part by water within, or adjacent to, the reinforced soil zone. We sincerely hope that our past writings and webinars are helping to correct, or at least minimize, this unfortunate situation from continuing into the future. Yet, there is one issue which has been, and continues to be, a serious omission in the design and construction of such walls. That is, the lack of a filter between fine-grained soils and gravel drainage layers in the reinforced soil zone.

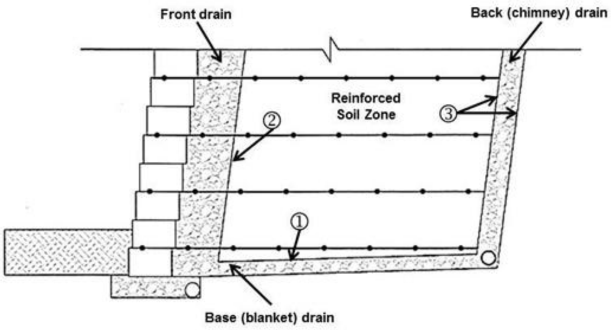

Figure 1. Base, Front and Back Drainage Locations (mod. from National Concrete Masonry Association, Herndon, VA, Pub. No. TR308, 2016)

NOTE: GSI webinars, referenced above, take place on the second Wednesday of every month (11:30 am – 1:30 pm, EDT). One of the biggest topics is MSE wall failures, design, performance, and monitoring.

MSE WALL FAILURES & GEOTECHNICAL FILTERS

To place fine grained backfill soils (note that 219 of the 301 failures (73%), used silt, clayey silt, silty clay or clay soils) against gravel drainage layers with water moving from the fine-to-coarse soils is a fundamental violation of soil filtration concepts. Shown first by Terzaghi in the 1930s, followed by Bertram in the 1940s and then by the Corps of Engineers in the 1950s, soil filter design using sand is an established practice in geotechnical engineering. There have been hundreds of researchers and practitioners since then (e.g., every geotechnical engineering professor worldwide) showing that the water will mobilize fine grained soil particles to migrate into the gravel's voids rendering its permeability greatly reduced, eventually becoming that of the fine grained soil. Thus, the gravel will no longer provide its intended purpose of drainage.

This is not a hypothesis, it is a known fact and can easily by reproduced in any soils or hydraulics laboratory!

Clearly needed in such cases is a filtration medium, sand, or geotextile, of which the latter is easy to place, economical, and readily available. Regarding geotextile filtration design, our keyword literature search shows 107 papers are available. See **GSI White Paper #35** for a review of both soil and geotextile filter design.

That said and with regard to MSE walls, there are three distinct locations within the standard MSE wall cross-section which are deficient in this regard. Their locations are shown on **Figure 1**.

Location 1 is easy to accommodate using a geotextile filter since it is simply laid on top of the horizontal base drain (also called blanket drain). Location 2 is more difficult construction-wise since each layer of soil between adjacent reinforcement layers must be wrapped accordingly. In so doing it becomes a mini wrap-around detail. In spite of the difficulty, it simply must be accommodated accordingly. Regarding Location 3, the geotextile filter must be on both sides of the back drain. This becomes a nightmare to construct using gravel as the back drain (also called chimney drain).

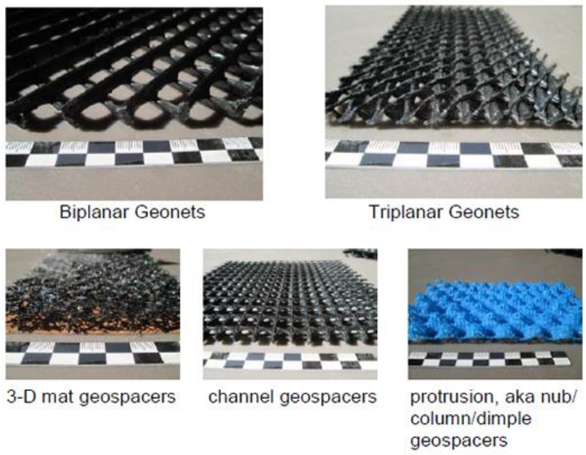

Figure 2. Geonet and geospacer drainage cores shown without their associated geotextile filters.

It begs the question, "Why use gravel soil to begin with?"

The straightforward answer to this situation is to omit the gravel and use a geocomposite drain. In this regard there are many types available under the two general categories of geonet composites and geospacer composites (**Figure 2**). Let's start using them on a regular basis and forget trying to stack a thin column of gravel vertically.

Figure 3. Toe failure of MSE wall caused by hydrostatic pressures.

At this point in time we know that there are far too many MSE wall failures and that the majority are mobilized by water within or around the reinforced soil zone. By designing and placing geotextile filters, the high permeability gravel of the front drain and base drain will be preserved. Even further, the use of drainage geocomposites for back drainage eliminates the contractor's challenge of building a near vertical column of gravel and furthermore geosynthetic drainage composites automatically come with geotextile filters bonded onto both sides of the drainage core.

We feel that by not providing geotextile-protected drainage to the front, base, and back drainage systems of MSE wall structures, long-term failures will result—most likely in the lower regions of the wall where hydrostatic pressures are highest (**Figure 3**).

Incidentally, the repair of such toe failures is incredibly difficult and expensive, and certainly looks bad for all parties involved and for the industry as a whole.

Dr. Robert M. Koerner is Director Emeritus of the Geosynthetic Institute, www.geosynthetic-institute.org. This article originally appeared in the June 2017 issue of the **GSI Newsletter**.

(Chris Kelsey /Geosynthetica, July 3, 2017
http://www.geosynthetica.net/mse-wall-failures-geotechnical-filters)

Best Practices for Minimizing Geomembrane Wrinkling

Catrin Tarnowski

Geomembrane wrinkling occurs, but it can be minimized. "Lay flat" geomembrane installations are quite possible, as they are documented all over the world. Truly, we can achieve this; yet, geomembrane wrinkling still happens.

How does wrinkling occur? It is connected to numerous decisions made in design, product selection, and installation procedures, and with boundary conditions on site. So how can we improve the total global practice?

Some important considerations and best practices are summarized here.

GEOMEMBRANE WRINKLING – MANAGING THERMAL EXPANSION

During installation, geomembranes will inevitably be exposed. (Indeed, the facility itself may be designed for a longer period of exposure or partial exposure as the geomembrane's service life begins.) As the liner sits in the open air, it may build up heat due to UV exposure or general rising temperatures in the environment at the job site. Thermal elongation can occur, no matter where the installation happens: Germany, Burkina Faso, Japan, South Africa, etc.

Thermal elongation is a reversible effect and can be controlled. The question that must be answered is how to design with additional slack or to design with anchoring and ballasting.

Some important points to remember:

- Waviness and dimensional stability must be considered together. The more "frozen" tension is in the product, the higher the variance in dimensional stability—developing waves when temperature changes occur. If the dimensional stability is controlled, liners stay flat or waves which occur can again disappear.
- Thermal expansion and contraction behavior, as well as stress relaxation, must be considered from design to operation
- Uncovered slopes are the most critical to monitor
- If geomembrane wrinkling or bridging does occur as a result of thermal expansion (or due to environment, wind uplift, cover placement, etc.), great care must be applied to any extra extrusion welds that are made.
- Lighter surface colors on a geomembrane, such as white geomembranes, reduce geomembrane wrinkling from thermal expansion.
- Waves that develop in a textured geomembrane have a higher tendency to remain than waves in a smooth liner
- Thickness has no real effect on wrinkling

In general, good practice can avoid the need to cut material or engage in additional welding. Experienced designers and installers are recommended.

GEOMEMBRANE INSTALLATION

Best practices in installation are vital to getting a geomembrane into service in as ideal condition as possible. This again underscores the importance of experienced geosynthetic installers.

Some considerations:

- When welding together geomembrane panels, the panels should have the same temperature to avoid wrinkling. Thus, a panel just unrolled should not immediately be welded to one that was installed the prior day or one which has been heating up for a while already. When panels of like temperature are welded—when the installer observes this proper sequencing—one can avoid the development of diagonal waves and waves in the weld area.
- Geomembrane rolls should be stored on a level surface and one must keep in mind how the site's environment may apply temperature effects to the rolls before they are even unrolled.
- Weld panels when they are flat

GEOMEMBRANE ANCHORING & BALLASTING

Large liner areas are sometimes built with insufficient anchor design. If those areas are left uncovered, geomembrane wrinkling and bridging can occur, due to wind uplift or temperature changes and the resulting movement they cause in the liner.

We can perhaps learn more from the many successful installations with very large liner areas, such as large dam lining projects or pumped storage ponds. In those applications, it is not uncommon to find the design incorporating intermediate anchoring to keep the whole lining system flat.

In regards to ballasting of a liner on site, we should as a field ask: Is ballasting an issue that we leave for the geomembrane installer to make decisions on? Or, can we actually specify particular methods for keeping a geomembrane flat? For example, the anchor bar method (Riegelbauweise) is one approach that has been used to keep a geomembrane flat during installation.

There are a variety of measures to keep liners flat, and specifying them does not necessarily have to impact installation progress (e.g., force the installation to take longer). Why not better utilize these approaches?

IMPORTANCE OF TEAM WORK

It must be stressed that to prevent geomembrane wrinkling, bridging, and voids, we must actively recognize the need to be part of a team. The designer, the installer, the CQA professional, and all other stakeholders in a project can and do influence the facility's success—and that includes down to whether wrinkles develop in the system.

Experience and communication are essential.

NOTE: Catrin Tarnowski (**GSE Environmental**) presented on this topic **in a special session at EuroGeo 6**.

Catrin Tarnowski works for GSE Lining Technology, Germany, www.gseworld.com.

(Chris Kelsey / Geosynthetica, June 6, 2017, http://www.geosynthetica.net/minimizing-geomembrane-wrinkling-tarnowski)

Secondary Geogrid Reinforcement in MSE Walls

Paul C. Frankenberger, P.E.; Matthew M. Merritt, P.E.; and Mark Myers, P.E.

The concept of secondary geogrid layers located at the face of a mechanically stabilized earth wall is similar to the use of secondary geogrid reinforcement in MSE reinforced slopes. In slopes, the secondary geogrid layers are used to stabilize the slope face between the primary geogrid layers. The result is closely spaced geogrid layers at the face of the slope. The long-term design strength (LTDS) of geogrid reinforcement is used in MSE design. The LTDS is determined by applying reduction factors to the geogrid ultimate tensile strength. Reduction factors account for creep resistance, chemical durability and installation damage. In allowable stress design of MSE walls, the LTDS is reduced by a factor of safety of 1.5.

In MSE walls, secondary geogrid reinforcement layers can be used between primary geogrid reinforcement layers. Secondary geogrid layers are located at the face of the wall and do not extend for the entire length of the primary geogrid layers. (See **Figures 1 and 2**.) The secondary geogrid reinforcement is used to redistribute high facing connection loads that occur from seismic loading and high overburden loads over a larger number of geogrid layers. This redistribution reduces the connection demand of the primary geogrid layers.

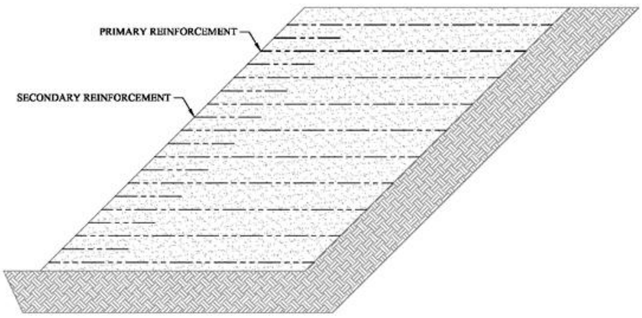

Figure 1. Secondary geogrid in MSE slope

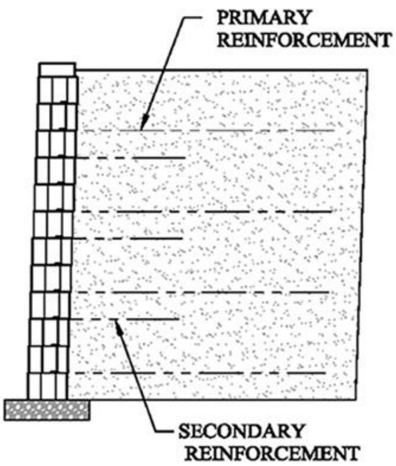

Figure 2. MSE wall with secondary geogrid

There are multiple types of MSE wall facing, such as segmental retaining wall (SRW) units, precast concrete modular (PCM) units, welded wire baskets, and rockery boulders. Secondary reinforcement has been used in frictional connection MSE facing that rely upon a connection based on friction of a geogrid layer inserted between the MSE wall facing. Secondary geogrid has also been used where it is placed behind larger MSE wall facing, such as with PCM units, gabion wire baskets, and rockery boulders. In these cases, the secondary layers do not connect to the facing. Secondary reinforcement has generally not been used for MSE walls that rely upon a mechanical connection between geogrid reinforcement and MSE facing units. The reason is that MSE walls units which feature mechanical connections are generally designed to have sufficient connection capacity such that the geogrid design strength governs and not the connection capacity.

SECONDARY GEOGRID REINFORCEMENT DESIGN APPROACH

A research study was conducted at the University of Kansas and sponsored by the Kansas DOT. The results of the study determined that secondary geogrid reinforcement reduces the load on the primary geogrid layers and the MSE wall face. This analysis can be calculated in common MSE wall software programs such as the National Concrete Masonry Association's SRWall 4.0 and MSEW 3.0, which was developed by Adama Engineering, Inc. The SRWall analyses show that with the exception of connection capacity, primary geogrid layers satisfy the overall active wedge stability and are sufficient to satisfy external stability (sliding and overturning). Insertion of secondary geogrids can be used to reduce the connection capacity demand of primary geogrid layers. Secondary reinforcement can be analyzed in MSEW, which allows the input of secondary geogrid layers as intermediate reinforcements. A minimum embedment length of three feet is given as typical length of intermediate reinforcement to develop resistance to connection load. The program uses the shorter intermediate layers to carry the facing load exclusively in the connection capacity evaluation. The intermediate or secondary geogrid layers are not used in the evaluation of other failure modes which rely only upon the primary geogrid reinforcements.

In software programs which are not set up for secondary reinforcement design (such as SRWall), the evaluation can be made by running two separate analyses, one with both primary and secondary reinforcement modeled as full-length layers and the other with the intended primary geogrid spacing. The primary geogrid can be shown to satisfy all failure modes but connection and the other analyses with primary and secondary reinforcement to satisfy all failure modes including connection. Additionally, a hand calculation can be performed to show that three feet is sufficient embedment to resist pullout of the secondary reinforcement.

The use of a secondary geogrid can create a closely spaced geogrid structure similar to geotextile-wrapped temporary walls using wire forms to support the fabric-wrapped face. The concept of closely spaced geosynthetic layers in permanent MSE walls is used in the Federal Highway Administration (FHWA) Geosynthetic Reinforced Structure (GRS) system (Adams et al. 2011). Research conducted at the University of Colorado in Denver concluded that closer spacing results in an apparent cohesion at the MSE wall face, as shown in **Figure 3** (Van Buskirk 2010). For soil in the reinforced zone, secondary geogrid layers result in locking in lateral stress from compactive effort, essentially arching the soil material between the geogrid layers. For shorter spacing, the arching effect is more pronounced, as indicated by the larger apparent cohesion shown in **Figure 3**. This technology was used in the design presented in the rockery case study described below.

PORTOLA SOUTH CASE STUDY: SRW UNITS MSE WALL

The Portola South project is a residential development located in Lake Forest, Orange County, California. The site is located within the foothills of the Santa Ana Mountains and has an elevation difference of 180 feet across the 93-acre site. Large fills were needed to level the site for residential building pads and segmental retaining walls were used to increase the usable area.

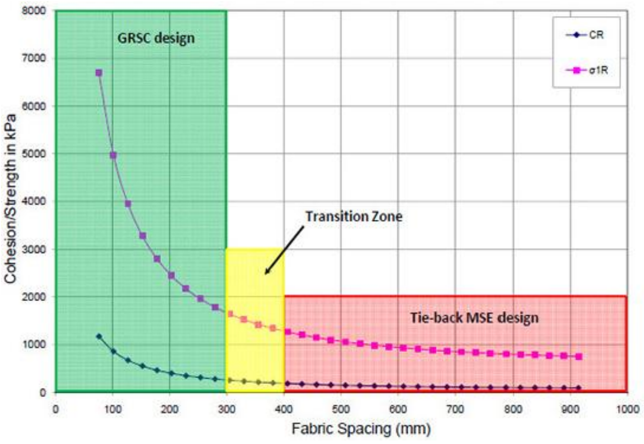

Figure 3. Effect of Reinforcement Spacing in MSE wall

There were 21 SRWs totaling 173,000 square feet of wall area. The owner selected the SRW facing type based on multiple wall options, including color, batter, and plantability. The geogrid design required a manufacturer offering a wide range of structural geogrid strengths and a strong quality control and quality assurance program. **Figure 4** shows a typical MSE wall section for the Portola South project.

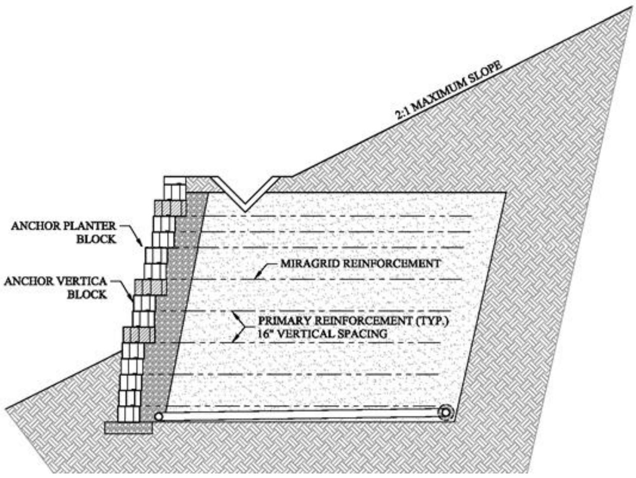

Figure 4. Typical MSE wall section with primary geogrid only

The tallest portions of fill on the site paralleled the western boundary and consisted of multiple tiered walls and 2:1 slopes. The fills were up 100 feet in height with the tiered walls up to 40 feet in height. The geogrids within the SRWs were designed to provide wall stability but were also increased in length and strength to resolve global stability issues. It was determined during the initial design phase that the friction connection capacity of the block and geogrid was controlling the design. That is, the loads at the face of the block were so high that the design required stronger and more frequently placed geogrid layers to satisfy connection capacity requirements than otherwise would be required for other failure modes. The loads at the face of the wall were greater than normal due to the large 2:1 slopes and additional tiered walls. **Figure 5** shows a site section from the Portola South project emphasizing the significant overburden loads on the lowest tiered wall.

Southern California is notorious for its earthquakes and high seismic loads. This project is no different. The walls were designed for a horizontal ground acceleration coefficient (Kh) of 0.18g, which corresponded to one third of the peak ground acceleration (PGA) of 0.54g. The seismic design for connection strength was the controlling factor in the geogrid design.

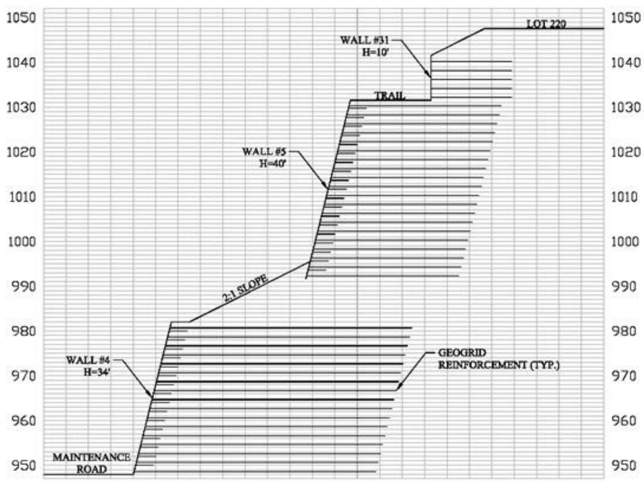

Figure 5. Portola South site section

When using the primary geogrid reinforcement-only design, the total area of geogrid needed was so great it affected the economics and installation speed of the SRW. The design solution was to use 4-foot-long secondary geogrid reinforcement placed at the face of the wall between the primary geogrid reinforcement layers to distribute the loads at the face of wall and reduce the connection capacity needed on the primary reinforcement layers. **Figure 6** illustrates an MSE wall section with primary and secondary geogrid reinforcement.

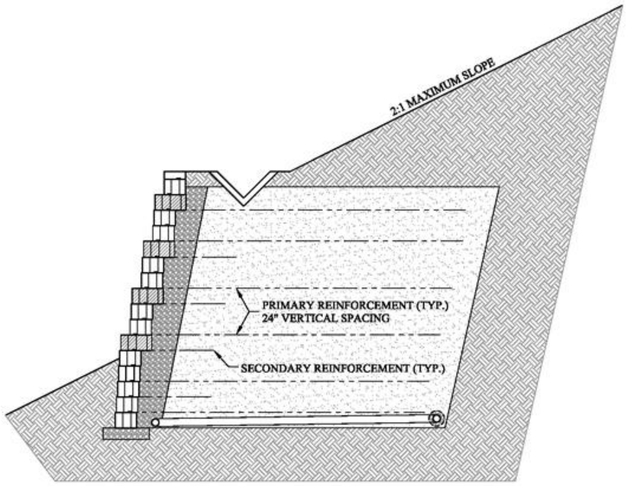

Figure 6. Typical MSE wall section with primary and secondary geogrid

The MSEW program was used for the design of the Portola South project according to FHWA design methodology (Berg et al. 2009). The MSEW program allows for the insertion of the secondary reinforcement to be used in the connection strength calculation while utilizing the primary geogrid for all other calculations.

The tallest section of Wall No. 4 can be examined to compare the use of primary geogrid only versus primary and secondary to determine the geogrid savings. **Table 1** shows the use of secondary reinforcement reduced the overall geogrid quantity by 28.7 percent while providing a structurally sound and economically feasible SRW system.

LAKE SHERWOOD PCM UNITS MSE WALL CASE STUDY

Lake Sherwood, California is an unincorporated community in the Santa Monica Mountains located within Ventura County. The 2013 – 2014 PCM unit retaining wall project consisted of the construction of eleven retaining walls which varied up to about 16 feet in exposed height. The walls were constructed to create a roadway and new lots within the luxury home development. PCM walls were selected for both their aesthetic rock face and for gravity wall applications at many locations. The configurations of the walls varied and included both cut and fill walls supporting both level and sloped conditions. PCM gravity walls typically worked to about 7.5 feet tall but required the use of larger 60-inch-deep concrete units. For walls in competent bedrock cuts even taller gravity walls were used. Static analyses of the retaining walls resulted in appropriate factors of safety.

	Primary Geogrid Length (FT)	Number of Layers per Foot Width	Secondary Geogrid Length (FT)	Number of Layers per Foot Width	Geogrid Area (SY/FT)
Primary Geogrid Reinforcement Only	54	25	0	0	150
Primary and Secondary Geogrid	54	17	4	11	107
Geogrid Savings					28.7%

Table 1. Percent reduction in geogrid area in Wall No. 4

Figure 7. Terraced SRW walls at Portola South project

Figure 8. Secondary geogrid at wall face at Portola South project

The geotechnical report recommended a PGA of 0.47g and the USGS website 2008 seismic deaggregation reported a PGA of 0.34g to have a 10% chance of exceedance in 50 years. The SRWall design software utilized Mononobe Okabe (M-O) methodology as described in the NCMA design manual (NCMA, 2010). Known limitations of the M-O method include high ground acceleration and tall slopes above and below MSE walls. For these reasons, the seismic analyses were decoupled to address internal and external failure modes. External failures modes of the MSE structure were analyzed in a manner similar to a reinforced slope. The pseudostatic seismic global stability analyses were completed which included the geogrid reinforcement. California Geologic Survey (CGS) Special Publication 117A (Guidelines for Evaluating and Mitigating Seismic Hazards in California) was used to select the pseudostatic coefficient using Figure 1 on page 30 of the document. The CGS method determined a pseudostatic coefficient of 0.24 for an earthquake having a PGA of 0.47g PGA. Seismic internal stability calculations were then performed using the highest value of PGA recommended by AASHTO (2002**)** of 0.29g. Both CGS and AASHTO assume some displacement as the basis for reducing the PGA. The internal stability analyses resulted in some connection overstressing in seismic.

For the design, 4-foot-long secondary geogrid reinforcement was used to manually distribute the load from primary geogrid to both primary and secondary reinforcement. **Figure 9** depicts a typical section for 28-inch-deep PCM units supporting fill. It should be noted that the design did incorporate positive connection PCM units to add additional resistance against toppling of the uppermost units in an earthquake. Use of secondary geogrid reinforcement resulted in cost savings and increased manufacturing efficiency compared to using standard 28-inch-deep PCM units. The use of secondary geogrid reinforcement allowed the manufacturer to meet the production efficiency needs of the project.

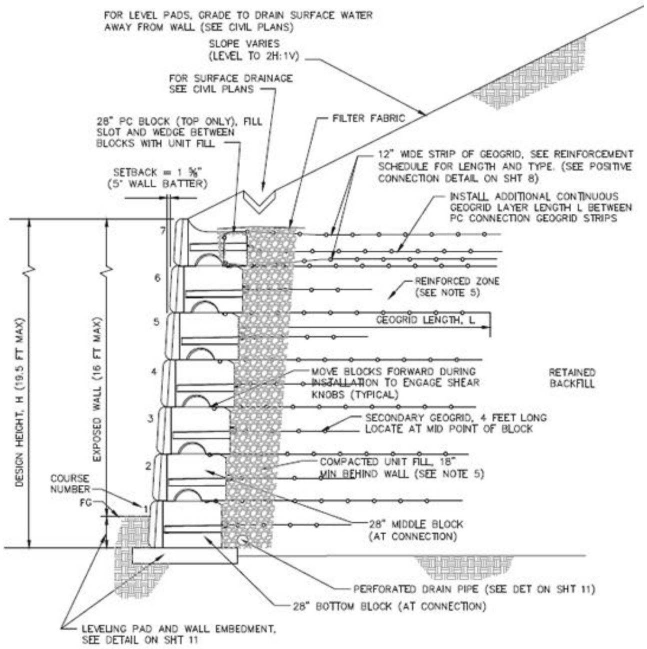

Figure 9. Typical PCM wall section with primary and secondary geogrid

SAN JOSE ROCKERY MSE WALL CASE STUDY

For a new subdivision in San Jose, California, rockery retaining walls were selected and approved by the City based upon their aesthetic appeal. The rockery walls were designed using the methods described in the FHWA's 2006 Federal Highway Lands manual, "Rockery Design and Construction Guidelines**.**" At one location, a rockery wall was to be constructed below an MSE slope. For design, it was assumed that construction of the MSE would occur first followed by excavation for the rockery wall and construction of the rockery.

The geogrid layout for the slope consisted of primary and secondary reinforcement. Shoring for construction of the rockery was designed as geogrid reinforcement for an MSE retaining wall. As noted earlier, the tight geogrid reinforcement functions like an apparent cohesion to provide a stable excavation with a near vertical cut. The geogrid layout for the slope and rockery is shown in **Figure 10**. The final design of the rockery assumed a flatter slope in design than the actual conditions to account for the benefit of the MSE and geogrid reinforced slope. For this project, the primary and secondary geogrid reinforcement provide an MSE structure which is then faced by the rockery wall instead of precast MSE wall units. There is no connection of the geogrid reinforcement to the rockery face. In this design, the primary and secondary reinforcement are the MSE facing which is then protected against weathering and erosion by the rockery wall. The entire reinforced earth structure was also evaluated using global stability analyses.

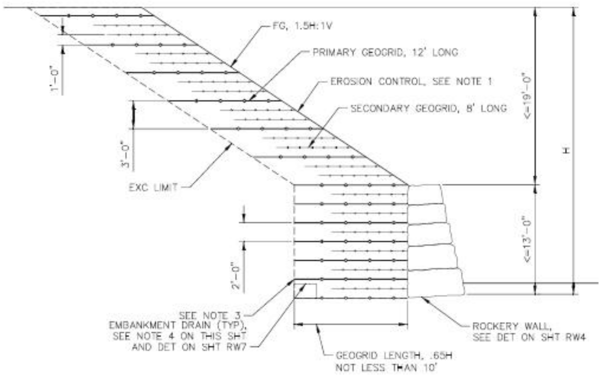

Figure 10. Typical geogrid reinforced rockery wall section

THE TAKEAWAY

Secondary geogrid reinforcement can be used in the evaluation of MSE walls to reduce cost and improve the performance of wall facing. In conditions of high seismic loading and overburden loading, MSE wall facing connection strength commonly controls the design, resulting in closely spaced primary geogrid reinforcement layers. The use of shorter secondary geogrid layers placed between primary geogrid layers can result in a more efficient and cost effective design.

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(Chris Kelsey / Geosynthetica, April 10, 2017, http://www.geosynthetica.net/secondary-geogrid-reinforcement-mse-walls)

Geosynthetic Reinforcement in CCR Surface Impoundment Closures

John D. Herrmann, Bruce A. Lacina, P.E., and Stephan M. Gale, P.E.

In-place closure of coal combustion residual surface impoundments presents numerous challenges. Common methods of capping include placing 0.46 m (1.5 ft) of a compacted clay soil cap with an additional 0.15 m (0.5 ft) of vegetated cover. Geomembranes and geosynthetic clay liners are often considered as viable, cost-effective options to clay. A difficult and critical component of the design and construction is accounting for unsuitable soil conditions. Gaining equipment access to the site in order to install the clay cap or geosynthetic cover can prove extremely difficult.

An excavator was nearly lost when soft, saturated CCR subgrade soil below the site's crust.

Current methods of constructing a working platform include placing large quantities of aggregate or sand. Contractors have also experimented with chemical stabilization utilizing lime or cement. High-strength, woven geotextiles offer a safe, cost-effective, and thoroughly engineered solution. Geotextile benefits include separation of the structural fill from the weak subgrade soils, excellent filtration, confinement, and reinforcement.

Another benefit is the ability of geotextile rolls to be sewn into large panels. This process accomplishes two important goals:

- The engineered seam between adjacent geotextile panels is reviewed during the design process to ensure it meets the stability analysis target factors of safety.
- Deploying sewn geotextile panels can eliminate safety concerns related to accessing the soft, saturated impoundment soils.

CCR SURFACE IMPOUNDMENT PROJECT BACKGROUND

A large United States electric utility initiated the closure of a CCR surface impoundment in 2015. Engineering plans and specifications were created for the project and were subsequently bid by three general contractors. The impoundment was approximately 8.1 hectare (20 acre) with a depth of ash estimated at 9.1 m (30 ft). Project grading plans indicated a balanced site, with 50% cut and 50% fill. Fly ash from the cut areas was to be used as fill material. The final cap included 0.46 m (1.5 ft) of compacted clay and 0.15 m (0.5 ft) of vegetated cover.

A view of the CCR surface impoundment site after crust vegetation removal.

THE CHALLENGE

After reviewing the submitted bids, the utility awarded the project and a notice to proceed was issued. The contractor began clearing the existing vegetated cover. It was quickly discovered that soft, unsuitable subgrade conditions existed below the firm, dry crust. Fortunately, there were no injuries when the excavator broke through the crust and was nearly lost.

Following completion of clearing operations for areas without standing water, the contractor pumped any remaining surface water from the impoundment.

Prior to geosynthetic installation, remaining surface water from the impoundment was removed by the contractor.

These activities made it apparent that reinforcement of the underlying soils would be necessary in order to complete the project safely and on time. The geosynthetic manufacturer met with the contractor onsite to describe the evolution of geosynthetic reinforcement materials for soft soil applications. A geosynthetic design alternative was prepared, one which would allow for the safe placement of both the fill material and compacted clay cap material.

CCR SURFACE IMPOUNDMENT REINFORCEMENT

Following the background presented regarding the evolution of reinforcement geosynthetics, the geosynthetic manufacturer prepared their recommended reinforcement solution to the contractor. Because a thorough soils investigation was not performed, several assumptions were made in the analysis and design stages.

A preliminary stability analysis was performed to assess geosynthetic reinforcement requirements for a cap consisting of a 1.83 m (6 ft) to 4.57 m (15 ft) of fill, 0.46 m (1.5 ft) compacted clay layer and a 0.15 m (0.5 ft) top erosion layer over the CCR material. The fill was modeled on a layer of high-strength, high-modulus geotextile to provide a construction platform for fill placement and to provide reinforcement for construction equipment traffic loading. The 4.57 m (15 ft) wide geotextile rolls were designed to be sewn together to provide the required level of reinforcement.

Property	Test Method	Unit	Minimum Avg. Roll Value	
			MD	CD
Tensile Strength – Ultimate	ASTM D-4595	kN/m	105	155
Tensile Strength @ 5% Strain	ASTM D-4595	kN/m	21	78
Tensile Strength @ 10% Strain	ASTM D-4595	kN/m	78	155
Tensile Strength – Cross Direction Seam[1]	ASTM D-4884	kN/m	-	80

[1]A J-seam or Butterfly seam is required.

Geotextile properties for the CCR surface impoundment project

The soft CCR subgrade material was modeled in design based on a review of onsite construction videos, photos and moisture test results. A global stability analysis to access performance becomes appropriate when the CCR soils are soft with depth. Additional design protocols include reviewing surface stability concerns utilizing an unpaved design methodology. A unit weight of 1,602 kg/m^3 (100 lbs/ft^3) and an unconsolidated, undrained shear strength of 9.6 kPa (200 lbs/ft^2) was assumed for the CCR material.

The analysis was completed using the computer program SlopeW by Geo-International. This program uses a two dimensional model. The Spencer method of slices was utilized, which satisfies both force and moment equilibrium. The program searches for critical failure surfaces. A sensitivity analysis was performed, which assumes the consolidated, drained CCR material would have a friction angle ranging from 27 to 37 degrees.

Panels were sewn in the factory into 22.9 m (75 ft) by 91.4 m (300 ft)

It was recommended that the geotextile be deployed in a sewn panel that is either fabricated on site and then pulled into place or sewn together at the project site. The fill was recommended to be placed and then spread in a direction which tensions the geotextile. If cracks or shifts occur during fill placement, then filling in that area should be stopped to allow the fly ash to settle and for excess pore pressures to dissipate. The analyses showed that pore pressure dissipation must occur in order for a consolidated fly ash friction angle to be achieved.

SURFACE IMPOUNDMENT CONSTRUCTION

Following a review of the proposed design recommendation by the contractor and owner, the geosynthetic manufacturer was authorized to proceed with manufacturing. The contractor decided to have the geosynthetic manufacturer sew panels in the factory rather than hire an installer to field sew the geotextile rolls. Panels were manufactured 22.9 m (75 ft) by 91.4 m (300 ft) and shipped to the jobsite. The contractor unrolled and deployed the panels over the impoundment. Fly ash fill was placed directly on the sewn, geotextile panel.

Placement of flay ash.

Fly ash fill placement proceeded quickly with no detrimental performance of the underlying subgrade. In cut areas, the geotextile panel was deployed and compacted clay was placed directly on top of the panel. The contractor quickly discovered that mud waves were forming in the CCR subgrade and construction was stopped. The geosynthetic manufacturer determined that pore water pressures were increasing in the subgrade, reducing shear strengths and causing mud waves. Although the geotextile material has a relatively high water flow rate and permittivity, dissipation of pore water pressure in the subgrade was limited by the relatively impervious clay material placed directly on top of the geotextile. The recommendation was made to add a geocomposite drainage layer directly on top of the geotextile to allow for better pore water dissipation.

Placement of geocomposite drainage layer directly atop the geotextile

Once the geocomposite provided an avenue for dissipation of water coming from the CCR subgrade, the mud waves receded and construction resumed.

Thus, what started as a virtually impossible surface impoundment closure due to soft, saturated subgrade conditions ultimately became a relatively simple and on-time construction project. This project was completed ahead of schedule and under budget. The use of high strength, sewn geotextile panels proved to be a cost effective and safe alternative to traditional methods. The owner, engineering consultant, and contractor were so satisfied with this closure method that an additional CCR surface impoundment is now being closed with a similar geosynthetic reinforcement method.

Construction resumed and the project was completed on time.

GEOSYNTHETIC RESEARCH

Using geosynthetics to improve the performance of gravel surfaced roads and loading pads and for undercut and stabilization applications has been done in the United States since the 1970s. Much like today's materials, early geosynthetics were either geogrids or woven or nonwoven geotextiles. Unlike today's design methods, most of the benefit from the geosynthetic in early designs was attributed primarily to tensile membrane support. The tensile membrane support function relies mainly on the presence of a geosynthetic in the cross section and not as much on the reinforcement strength of the geosynthetic used. The geosynthetic design tools created during this time reflected these early tensile membrane concepts (e.g., Heukelom and Klomp 1962, Barenberg, et. al. 1975, Steward, et. al. 1977, Giroud and Noiray 1981).

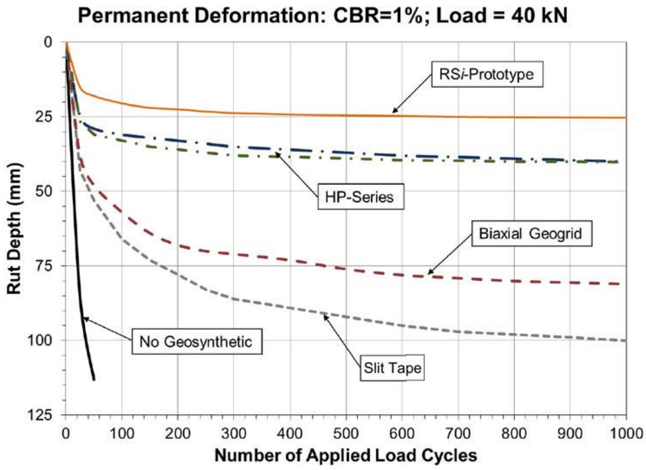
Engineers, contractors, owners, and geosynthetic manufacturers have realized through continuous product development and improvement that newer geosynthetics with integrated mechanical properties can provide a measureable benefit over the earlier geosynthetics used in these applications. As a result, there are currently many more types and strengths of stabilization and reinforcement geosynthetics than were available in the 1970s. Modern design theories are able to incorporate the use of these newer geosynthetics when they have been properly calibrated to the performance of the material (Giroud and Han 2012).

Early geotextiles included 136 g/m^2 and 271 g/m^2 (4 and 8 oz/yd^2) nonwovens and 890 N and 1.33 kN (200 and 300 lb) slit tape wovens. Nonwoven geotextiles were created to provide excellent separation, filtration, and drainage capacities. Newer geotextiles have been developed to fill demands created for better controlled filtration and drainage capacities and for higher reinforcement capacities, as well as the need for lower elongation under sustained loading conditions. High performance (HP) woven geotextiles were created to provide high tensile strength stabilization and reinforcement capacities. The newest RS*i*-Series roadway construction geosynthetics, for example, incorporate the improvements of more than forty years of product development and successful project histories.

HP woven stabilization and reinforcement geotextiles were first introduced in the 1980s and continue to be improved and refined. HP woven geotextiles have a long history of high performance and significant cost savings in subgrade stabilization and pond capping applications. Research into the functions and behaviors of these geosynthetics in these applications (Christopher and Lacina 2008) have led to the development of TenCate's current Mirafi® RS*i*-Series and H2R*i* stabilization/reinforcement geotextiles. These new geosynthetics have optimum integrated functions of layer separation, reinforcement strength, filtration and drainage capacity, and soil/aggregate interaction.

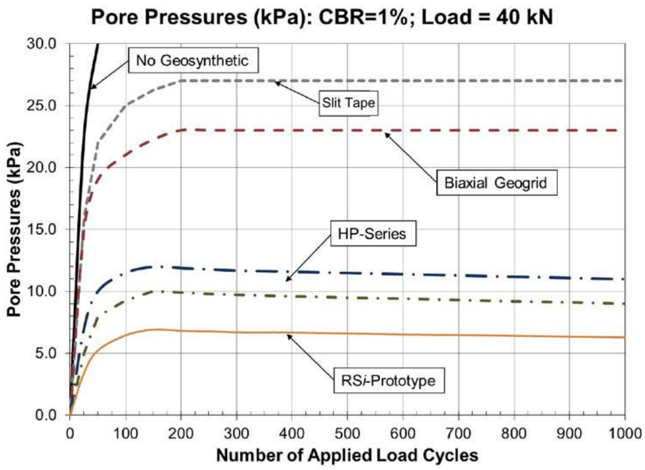
LABORATORY GEOSYNTHETIC TESTING

Both small-scale and large-scale laboratory testing have been performed over the years on geosynthetics to determine their relative performance and behaviors in different soil and gravel fills and under different loading conditions. Small-scale laboratory testing includes cyclic and monotonic pullout interaction, direct shear interaction, and filtration and drainage capacity. Large-scale laboratory testing includes the application of simulated wheel loads from truck traffic to compare, refine, and develop reinforcement/stabilization geosynthetics.



Cyclic Load Testing Surface Deformations as a Function of Applied Loads

Test sections were constructed in a 2 m X 2 m (6.5 ft X 6.5 ft) X 1.5 m (5 ft) deep test box with removable facing that provided access to the interior. A 300 mm (12 in) diameter steel plate placed on a rubber pad was used to simulate wheel loads that provided a more uniform contact pressure on the test section surface. The applied loads and load frequency simulated a 40 kN (9 kip) wheel load or 80 kN (18 kip) axle load.



Cyclic Load Testing Subgrade Pore Pressure as a Function of Applied Loads

Another significant role geosynthetics contribute to subgrade stabilization is to quickly and efficiently dissipate pore pressures developed in the subgrade soil during dynamic loading.

The loading and data collection software were set up to provide a linear load increase from zero to 40 kN (9 kips) over a 0.3 second rise time, followed by a 0.2 second period where the load is held constant, followed by a load decrease to zero over a 0.3 second period and finally followed by a

0.5 second period of zero load before the load cycle is repeated, resulting in a load pulse frequency of 0.67 Hz. The maximum applied load of 40 kN (9 kips) resulted in a pavement pressure of 552 kPa (80 psi). This load represents one-half of an axle load from an equivalent single axle load (ESAL). The load frequency is selected to allow the data acquisition system time to store data before the next load pulse was applied.

Large-scale lab testing of developmental RS*i*-Series geotextiles showed clear reductions in surface rutting behavior in large-scale testing compared to HP woven or slit tape woven geotextiles and geogrids. The RS*i*-Series geotextiles also provided better pore pressure dissipation during dynamic load testing and higher pullout resistance in common roadway geotechnical fills than previous woven stabilization/reinforcement geotextiles.

*

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(Chris Kelsey / Geotechnica, May 9, 2017, http://www.geosynthetica.net/geosynthetic-ccr-surface-impoundment-closure)

Geosynthetics Education: A Case Study

Preston Kendall

The **International Geosynthetics Society** has set a goal of getting geosynthetics engineering information into undergraduate civil engineering programs. This is being accomplished in part through the international **Educate the Educators program** and the newly created Educate the Students program. The larger task of outreach is certainly ambitious. The fields of civil and geotechnical engineering are "as old as dirt," but geosynthetics have only been around since the 1950s, and the field's formal terms did not begin to crystallize until 1977 when Dr. JP Giroud coined "geotextile" and "geomembrane" in a lecture at what is now recognized as the 1st International Conference on Geosynthetics.

Dr. Giroud (center), seen here at the Paris conference in 1977, coined the terms "geotextile" and "geomembrane." What might we know geosynthetics as today had he not contributed that paper?

These polymeric materials have enjoyed a monumental rise in adoption into applications over the last 40 years, but I was in university not long ago and I don't recall the word *geosynthetics* having ever been presented in my curriculum. In fact, I grew up and received two college degrees in a US state that I later learned to be an international geosynthetics hub: Georgia.

FINDING WORK

When I was in my last semester of civil engineering graduate school, I came across a job description that appeared to be written with me in mind. It offered opportunity to learn from experienced civil engineers, to get field work on large civil sites, to work in a lab, to do research and publish papers, to learn the commercial side of civil engineering, and to interact with civil designers regularly. As I was soon to graduate, I thought, wow, this is my dream job!

There was one other key detail in this job description: I would be working in the field of "Geosynthetics". Huh?

I had a vague notion of what geosynthetics were. I had seen the identically dressed people at career fairs with branded collared shirts. They would enthusiastically show you samples of black plastic grids and synthetic fabrics. They didn't represent any household names like some of the other companies at the career fair, but through them I became aware that there was an industry behind the use of synthetics in civil and environmental engineering. I had also done a somewhat related senior project involving inflatable rubber dams, but I still don't recall the word geosynthetics ever coming up during that project or the 8 years of university education.

Apparently, it was an area where my academic life was just touching the surface of what students call "the real world."

Photo of bidim geotextile installation from Geofabrics Australasia

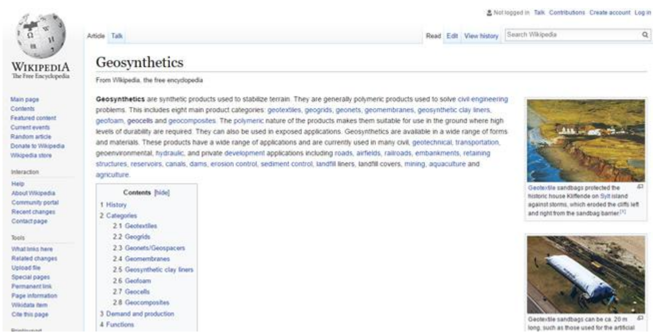
Most students are aware that there is a difference between student life and the real world. They realize that there is much to learn in those first crucial years in the work force. But what if you came across a job that was based on materials that were never even mentioned in your university program? This is where I found myself in 2012.

I looked to my professors to get some reassurance. One response that stands out in my memory was from a geotechnical professor who said that geosynthetics are analogous to steel reinforcement in concrete. This was about where my geosynthetics education in university began and ended.

ENTERING THE FIELD … ONLINE

A month after graduation, my professional education began. I read up on geosynthetics as best I could in the few weeks between graduation and day one in the workforce. They say "you don't know what you've got till it's gone". This was very true of the literature access that university enrolment allows. After graduation, *Poof!* It was gone. My unlimited access to journal publications was gone.

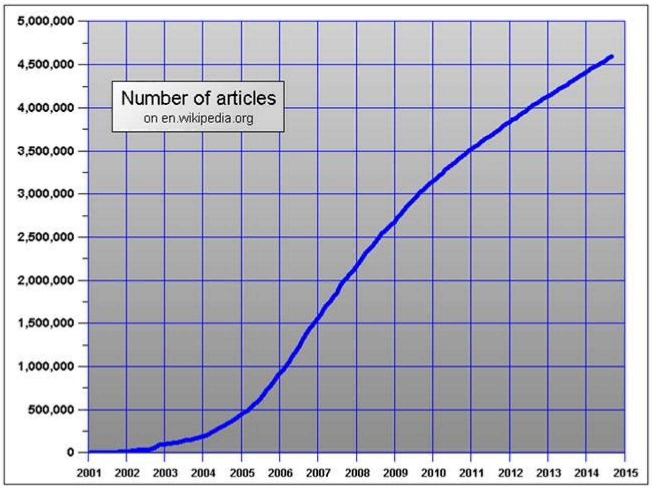
The internet became my best source for geosynthetics information.



Wikipedia was one of my main sources. It's a website that has grown dramatically in line with my own education from middle school through completing my civil engineering graduate program.

When you search something and Wikipedia is one of the top results, it is usually a good indication that you have found something real.

When I googled *"geosynthetics"* back in 2012, Wikipedia's entry was one of the top results. What I found was not much different from what you find in that same entry today. It is useful but in no way comprehensive. It introduced the diversity of geosynthetic products, but provided very little information on the science and engineering behind the materials.



Locating abstracts in online journals, including abstracts for papers authored by some of my future colleagues, provided a bit more, but without an expensive subscription to these publications I did not have access.

I did not know back then that International Geosynthetics Society members have free access to the IGS Journals: Geosynthetics International and Geotextiles & Geomembranes. Both journals are rated in the Top 10 of the 230+ geotechnical journals rated by SCImago.

There may have been a time in my life when I would have been ashamed to write publicly about how I used (and still use!) Wikipedia. After all, the entries can be written by anybody and they are not always properly vetted. But, the website has an important place—particularly for introduction to information we might pursue on a deeper level. It is part of this new era of digital exchange. We expect information to be at our fingertips and we want it fast. The internet has allowed for this change and Wikipedia has done a good job of delivering.

Today, being wiser about digital resources, I know that civil engineers and students of civil engineering have a number of freely available resources to consult beyond Wikipedia. These include sites such as:

- **International Geosynthetics Society** – IGS has numerous general and technical documents freely available on its website. Plus: members get free electronic access to the IGS Journals and free access to an online database of more than 1800 proceedings papers. *Student memberships are free*! Also, many IGS chapters have free or nominal fees for student members.

- **IGS Chapter websites** – There are more than 40 international chapters of the International Geosynthetics Society, and many of them openly share documents, presentations, and even some papers, such as from their national conferences. These resources are routinely published in the primary language of the country or region in which these chapters are based.

- **Geosynthetic Institute** – GSI has more than 30 technical white papers for free access on its website. Its generic specifications are also of tremendous value for learning about how geosynthetics are determined to be of high quality and suitable for an application.

- **Geosynthetica** – The Geosynthetica family of publications began in 1999. (Wikipedia was founded in 2001.) The online publications are open to all and do not require any registration. Editions include an international **English-language site**, a Portuguese-language site **focused on the Brazilian geosynthetics field**, a Spanish-language website concentrating on **Central and South American geosynthetics work**, and a very new **Russian-language feed** for geosynthetics information.

- **Geosynthetics companies** – Not to be overlooked! Geosynthetics manufacturers, installers, and consultants regularly publish papers or versions of their conference papers on their own websites. They also produce unique technical documents and project references that provide details of how to properly utilize geosynthetics. (My own employer, **Geofabrics Australasia**, has produced educational videos, published case histories, authored material selection articles, and more.)

BACK TO MY GEOSYNTHETICS EDUCATION & CAREER

Less than two months after graduating with a Master's in Civil Engineering, I was working for a geosythetics manufacturer on the other side of the world. I had grown up in the geosynthetics-producing state of Georgia in the United States, but it wasn't until I entered the engineering work force with an adventurous 10,000-mile move to Australia that I really began to understand the value of all the geosyntetic publications out there. It was also where I began to understand one of the great benefits of being a member of the International Geosynthetics Society.

Before I had attended any meetings, participated in any committees, or read any newsletters, I was using my membership extensively through its fantastic publication access. I had lost all of the web access to journals that my university provided but now I could access the key journals relevant to my industry.

Photo by Geofabrics Australasia

My university education did a great job on the "geo" portion of "geosynthetics," and I have been able to put my foundation in science and engineering to good use. The "synthetics" portion, however, is something I've had to discover and explore since I entered the workforce.

It has been a very engaging and rewarding experience so far.

Among new civil engineering graduates, my experience was unique. Many of my classmates entered different sectors of the civil and environmental engineering field. I'm sure that they come across geosynthetics in their roles, but I am fairly certain that they do not have a good grasp of all the science and potential that is behind geosynthetics and their applications. More than likely, many of them still see geosynthetics as I did when I first came across it at the career fair.

I now know that geosythetics are commonplace in "the real world". They support the ground I walk on and the roads I drive on. They protect the water I drink and the land I use. These are fundamental tasks of civil infrastructure.

Geosynthetics as a civil engineering discipline is real, it is here, and it is growing rapidly. It is critical that we prepare the next generation of engineers to meet an industry that has become fundamental to modern geotechnical practice. Civil engineers have a moral duty to society and society demands proper application of geosynthetics. Promoting the appropriate application of geosynthetics is the core principle of the International Geosynthetics Society and to support this principle, the organization is endeavouring to make geosynthetics part of the undergraduate curriculum of the civil engineering field.

I believe there is something else we can all do to promote the appropriate use of geosynthetics.

In assisting this effort, here are my recommendations:

- Embrace the internet and open sharing of information

- Wikipedia has huge potential. **Join the community on Wikipedia and contribute content** or help vet content and add citations to strengthen the material. For other venues, such as Geosynthetica, contribute an article (as I have this one). Co-author a paper for a conference, particularly those under the IGS Auspices so that the information has a greater chance of being added to the IGS's extensive online library for its members.

- Join the International Geosynthetics Society. Consider joining a committee. Attend an event. Contribute something to the IGS News.

Start small but remain involved. This is a strong, ever-growing field. It influences every sector of civil engineering. Whether you are in the field or in school, your voice is important. Take advantage of the easily available resources on the internet, interact with their publishers, and become a contributor.

*Preston Kendall is a Business Development Manager with **Geofabrics Australasia Pty Ltd** and a member of the **IGS Young Members Committee** (IGS-YMC).*

(Chris Kelsey / Geosynthetica, June 11, 2017, http://www.geosynthetica.net/geosynthetics-education-case-study-kendall)

ΝΕΑ ΑΠΟ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

ΕΛΛΗΝΙΚΟΣ ΣΥΝΔΕΣΜΟΣ ΓΕΩΣΥΝΘΕΤΙΚΩΝ ΥΛΙΚΩΝ
HELLENIC GEOSYNTHETICS SOCIETY

ΔΕΛΤΙΟ ΤΥΠΟΥ

Ο Ελληνικός Σύνδεσμος Γεωσυνθετικών Υλικών την Παρασκευή 19 Μαΐου 2017 συνδιοργάνωσε με το Εργαστήριο Εδαφομηχανικής & Θεμελιώσεων του τμήματος Πολιτικών Μηχανικών του Δημοκριτείου Πανεπιστημίου Θράκης και τον Όμιλο Πλαστικά Θράκης ημερίδα με τίτλο "**Γεωσυνθετικά Υλικά σε Έργα Πολιτικού Μηχανικού**".

Μέλη Δ.Σ. HGS

Την ιδιαίτερα επιτυχημένη ημερίδα παρακολούθησαν περισσότερα από 200 άτομα, η πλειοψηφία των οποίων ήταν φοιτητές του ΔΠΘ. Η ημερίδα πραγματοποιήθηκε στο Αμφιθέατρο Α2 του Νέου Κτιρίου Πολιτικών Μηχανικών ΔΠΘ στην Πανεπιστημιούπολη Κιμμερίων - Ξάνθη.

Κατάλογος της θεματολογίας και των εισηγητών της ημερίδας παρουσιάζεται ακολούθως, ενώ όλες οι παρουσιάσεις είναι διαθέσιμες στον ιστότοπο του Ελληνικού Συνδέσμου Γεωσυνθετικών Υλικών (www.igs-greece.gr).

- Κολλιός Α. "Εισαγωγική ομιλία – Είδη & Εφαρμογές Γεωσυνθετικών Υλικών".
- Μάρκου Ι. "Εδάφη Ενισχυμένα με Γεωυφάσματα – Μηχανική Συμπεριφορά και Αλληλεπίδραση Υλικών".
- Κλήμης Ν. "Ανάλυση & Σχεδιασμός Οπλισμένων Επιχωμάτων: μεθοδολογία, εφαρμογή και κρίσιμες παράμετροι".
- Ζευγώλης Ι. "Πιθανοτική ανάλυση τοίχων αντιστήριξης οπλισμένης γης".
- Τσάτσος Ν. "Η χρήση Γεωσυνθετικών υλικών σε γεωπεριβαλλοντικά έργα - Η περίπτωση των ΧΑΔΑ".
- Μουτάφης Ν. "Στεγάνωση Φραγμάτων βαρύτητας με γεωσυνθετικά υλικά".
- Δρουδάκης Α. "Χρήση των Γεωσυνθετικών σε ΧΥΤΑ".
- Καραβασίλη Σ. "Σχεδιασμός Οδοστρωμάτων με Χρήση Γεωσυνθετικών Υλικών".
- Στρατάκος Χ. "Εφαρμογές γεωσυνθετικών υλικών σε τάπητες ασφαλτικού σκυροδέματος".
- Φίκιρης Ι. "Καινοτομίες με χρήση γεωσυνθετικών υλικών".

Η θεματολογία των εισηγήσεων της ημερίδας κάλυψε, λόγω χρονικών περιορισμών, μόνον ένα μέρος εκ των πολυάριθμων εφαρμογών των γεωσυνθετικών υλικών σε έργα πολιτικού μηχανικού. Παρουσιάσθηκαν εφαρμογές σε γεωτεχνικά, γεωπεριβαλλοντικά, υδραυλικά έργα καθώς και σε οδοστρώματα.

Προεδρείο 1ο μέρος Ημερίδας

Η διοργάνωση της ημερίδας υποστηρίχθηκε γενναιόδωρα από τον Όμιλο Πλαστικά Θράκης με την ευγενική χορηγία πλούσιων εδεσμάτων κατά τη διάρκεια των διαλειμμάτων στους συμμετέχοντες, με την παροχή σύγχρονων οπτικοακουστικών μέσων, διευκολύνοντας τις παρουσιάσεις των ομιλητών, και γραμματειακής υποστήριξης. Το Δ.Σ. του Ελληνικού Συνδέσμου Γεωσυνθετικών Υλικών ανακοίνωσε την διοργάνωση διαγωνισμού μεταγλώττισης στα Ελληνικά ολιγόλεπτης ταινίας που έχει δημιουργήσει ο Διεθνής Σύνδεσμος Γεωσυνθετικών Υλικών (IGS) με θέμα γεωσυνθετικά υλικά και αειφορία με βραβείο καλύτερης παραγωγής, χρηματικό έπαθλο 500$, που χορηγείται από το IGS. Περισσότερες πληροφορίες θα αναρτηθούν συντόμως στον ιστότοπο του Ελληνικού Συνδέσμου Γεωσυνθετικών Υλικών.

Προεδρείο 2ο μέρος Ημερίδας

Στα πλαίσια της ημερίδας πραγματοποιήθηκε μεσημεριανή επίσκεψη με πούλμαν στις εργοστασιακές εγκαταστάσεις του Ομίλου Πλαστικά Θράκης στο Μαγικό Ξάνθης όπου οι συμμετέχοντες είχαν την ευκαιρία να περιηγηθούν στις γραμμές παραγωγής υφαντών και μη υφαντών γεωυφασμάτων.

Το Δ.Σ. του Ελληνικού Συνδέσμου Γεωσυνθετικών Υλικών

Αναστάσιος Κολλιός, Πρόεδρος

Γιάννης Φίκιρης, Αντιπρόεδρος

Νικόλαος Τσάτσος, Υπεύθυνος Οικονομικών

Απόστολος Ρίτσος, Γραμματέας

Γιάννης Μάρκου, Μέλος

Χρήστος Στρατάκος, Μέλος

Δημήτριος Ζέκκος, Μέλος

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

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

ASIA 2018 Seventh International Conference and Exhibition on Water Resources and Renewable Energy Development in Asia, 13-15 March 2018, Danang, Vietnam, www.hydropower-dams.com/asia-2018-conference.php?c_id=303

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ICGIMSES 2018

20th International Conference on Ground Improvement and Mechanically Stabilized Earth Structures

March 15 - 16, 2018, London, United Kingdom

https://waset.org/conference/2018/03/london/ICGIMSES

The **ICGIMSES 2018: 20th International Conference on Ground Improvement and Mechanically Stabilized Earth Structures** aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Ground Improvement and Mechanically Stabilized Earth Structures. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Ground Improvement and Mechanically Stabilized Earth Structures.

The **ICGIMSES 2018** : 20th International Conference on Ground Improvement and Mechanically Stabilized Earth Structures is the premier interdisciplinary platform for the presentation of new advances and research results in the fields of Ground Improvement and Mechanically Stabilized Earth Structures. The conference will bring together leading academic scientists, researchers and scholars in the domain of interest from around the world. Topics of interest for submission include, but are not limited to:

- Ground improvement
- Ground improvement techniques
- Geosynthetics
- Stabilization of soil for various purposes
- Deep vibro techniques
- Dynamic compaction
- Prefabricated vertical drains
- Permeation grouting
- Jet grouting
- Soilfracture grouting
- Compaction grouting
- In-situ soil mixing
- Dry mixing
- Vibro compaction
- Vacuum consolidation
- Preloading of soil
- Soil stabilization by heating or vitrification
- Ground freezing
- Vibro-replacement stone columns
- Mechanically stabilized earth structures
- Soil nailing
- Micro-piles
- Grouting
- Preloading or pre-compression of soil for ground improvement
- Applications
- Thermal stabilization of soil for ground improvement
- Vibro-replacement stone columns for ground improvement
- Applications of mechanically stabilized earth structures

Conference Information and Registration
http://waset.org/conferences/2018/03/london/ICGIMSES

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ICGIT 2018

20th International Conference on Ground Improvement Techniques

March 15 - 16, 2018, Paris, France

https://waset.org/conference/2018/03/paris/ICGIT

The **ICGIT 2018: 20th International Conference on Ground Improvement Techniques** aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Ground Improvement Techniques. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Ground Improvement Techniques.

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Conference Information and Registration
http://waset.org/conferences/2018/03/paris/ICGIT

2nd Annual International Tunnelling and Underground Space Conference
Promoting the Use of Our Underground Space
Exploring the Socioeconomic Benefits of Developing Tunnelling and Underground Space Infrastructure in Nigeria
20-22 March 2018, Abuja FCT, Nigeria
http://tunnellingnigeria.org

Underground Use Space Seminar

All day Seminar on Underground Space use (Facilitated by Experts from the International Tunnelling and Underground Space Association Committee on Education and Trainning and the International Tunnelling and Underground Space Association Committee on Underground Space Use). This Seminar is open to Professionals within the Engineering , Geo sciences, Architectural , Urban and Regional Planning, Legal and Project Finance ,Student as well as Policy Makers.

Registration is free but mandatory to attend this session .

Objective: Introduction for engineers, architects, planners and public administrators to the use of underground space to increase liveability and sustainability in urban areas and in other key public resource regions. The seminar will identify key issues that need to be considered when using underground space and will show how these key issues are dealt with on a worldwide basis.

Session 1: Introduction and Overview of the main issues

- Advantages and disadvantages of underground solutions
- Solutions and missed opportunities for underground projects
- The key stakeholders and their role and responsibilities
- The main stages in a tunnel project management

Session 2: Organisation and planning

- Sustainability and resiliency issues
- Underground utilities and services in urban areas
- Case study 1: Example of a metro network management
- Case study 2: Microtunnelling and underground service network
- Discussion and closing Remarks

Conference / Panel Session

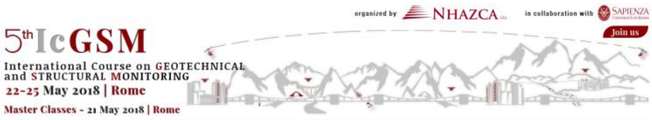
Conference Presentation and Panel sessions Conference theme: "The Socio Economic benefits of Developing Tunnelling and Underground Space Infrastructure in Nigeria" This session will also feature the official launch of the "Think Deep Naija Campaign"

Registration for this session is free but mandatory

Register for the conference at: www.tunnellingnigeria.org

For further information:
Email: info@tunnellingnigeria.org
Mobiles: +23408037048223
+447909223866

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



5th International Course on Geotechnical and Structural Monitoring
22 - 25 May 2018, in Rome
www.geotechnicalmonitoring.com

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

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

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

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

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

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

John Dunnicliff and Paolo Mazzanti

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

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

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

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

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micro to MACRO
Mathematical Modelling in Soil Mechanics
May 29-June 1, 2018, Reggio Calabria, Italy
www.microtomacro2018.unirc.it

Three Symposia on granular or porous issues have already been held in Reggio Calabria with the participation of many outstanding scholars in the field. The new proposed Symposium will be an occasion to enhance the scientific debate about the construction of mathematical models for the description of the physical behaviour of soils, as well as about the suggestions obtained from the micro-mechanical observation of the matter.

The attention will be focused on the comparison between the appropriateness of models and the needs of mathematics to get rigorous results. Skills from applied mathematical physics, geotechnical engineering and mechanics are then involved. It is well known that granular matter displays, in fact, subtle complexity. Phenomena like strain localization, liquefaction of solids, cyclic mobility, effects of diagenesis, weathering, compaction and segregation may imply sophisticated models and sometime render questionable traditional approaches. Moreover, these models suggest non-trivial mathematical problems that are interesting *per se*. Engineering requests of applicability need also to be satisfied for civil and geotechnical purposes. All these issues may be open to discussion during the Symposium, though the emphasis will be on modelling: higher order continua, incrementally nonlinear laws and micro-mechanical considerations must be taken into account.

Guest speakers will present complementary issues from the fields of geotechnical engineering, statistical physics and applied mathematics that can be considered together as a short advanced course on the topic. Regular presentations are also intended to cover fields from mathematical physics to civil and geotechnical engineering, with the discussion of theoretical, numerical and experimental results.

MAIN TOPICS

- continuum modelling;
- mechanics of porous materials;
- multiphase flows;
- discrete element modelling;
- micro-macro in soil-mechanics;
- granular flows;
- transport phenomena in particulate materials;
- hydro-thermo-chemo mechanical coupling;
- laboratory testing and modelling;
- mechanics of saturated and unsaturated soils.

Secretariat

DICEAM, Via Graziella, Feo di Vito, I-89122 Reggio Calabria, Italy; email giuseppe.mortara@unirc.it; phone: +39 0965 1692 271.

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www.dfi.org/dfieventlp.asp?13310

This conference will explore the industry's challenges presented by owners and owners' representatives (consultant/construction managers) who are associated with building the infrastructure systems that meet modern demands. Also, the event will be the forum for presentations from contractors, engineers, researchers and manufacturers (technology providers) on projects and studies related to new technologies, methods of construction, design concepts, equipment, materials and electronic in connection with the developing of Project Information Management

System (PIMS) and the Building Information Modeling (BIM) applied to the geotechnical and foundation industry.

Reasons to Attend this Conference

1. Share international experiences with worldwide experts.
2. Interact with practitioners specializing in cutting-edge technologies for deep foundations and ground improvement.
3. Discuss and debate technical topics related to deep foundations and ground improvement, particularly critical infrastructure, soft soils, piling-related design, equipment and material advancements, modeling and computing for new techniques and monitoring practices.
4. Participate in risk-related discussions, including failures and lessons learned on case histories from the perspectives of owners, contractors and engineers and integrated risk management processes.
5. Hear about DFI and EFFC's research initiatives aimed at advancing the state-of-practice of deep foundations and excavation support.
6. Explore the Exhibition Area featuring specialty services of participating companies.
7. Attend the pre-conference workshops on working platforms, continuous flight auger (CFA) and drilled displacement pile practices, and Tremie concrete research and guidance document updates.
8. Make the most of your time in Rome — it wasn't built in a day and you'll need plenty of time to explore while attending the joint DFI-EFFC Conference!

Questions? Email us at events@dfi.org

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

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

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

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

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

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

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ICSSTT 2018

20th International Conference on Soil Stabilization Techniques and Technologies

July 19 - 20, 2018, Toronto, Canada

https://waset.org/conference/2018/07/toronto/ICSSTT

The ICSSTT 2018: 20th International Conference on Soil Stabilization Techniques and Technologies aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Soil Stabilization Techniques and Technologies. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Soil Stabilization Techniques and Technologies.

The **ICSSTT 2018** : 20th International Conference on Soil Stabilization Techniques and Technologies is the premier interdisciplinary platform for the presentation of new advances and research results in the fields of Soil Stabilization Techniques and Technologies. The conference will bring together leading academic scientists, researchers and scholars in the domain of interest from around the world. Topics of interest for submission include, but are not limited to:

- Soil stabilization
- Modern soil stabilization techniques
- Soil stabilization methods with different materials
- Soil stabilization methods and materials
- Soil stabilization processes and technologies
- Soil stabilization by chemical methods
- Design procedures for soil modification or stabilization
- Mechanics of soil stabilization and modification
- Soil stabilization with cement
- Soil stabilization using lime
- Soil stabilization with bitumen
- Chemical stabilization of soil
- Electrical stabilization of clayey soils
- Soil stabilization by grouting
- Soil stabilization by geotextiles and fabrics
- Soil stabilization for roads and airfields
- Soil stabilization in pavements

Conference Information and Registration
http://waset.org/conferences/2018/07/toronto/ICSSTT

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

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

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

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

World economy is changing rapidly. On the one hand, issues like health and safety, quality, resilience, sustainability, social justice and environment are increasing their weight for decision makers compared with traditional pecuniary considerations.

On the other hand, the advent of cheap powerful computers, smart phones and robots is changing society drastically and also the economic interactions.

The general agreed on professional requirements for future generations are the ability to interact with computers and robots, and the ability to do what these are not able to do (the so called soft skills as ethics or creativity).

Civil Engineer practice is also impacted by this change.

In the frame of Bologna Treaty, most universities are striving to adapt their educational contents as well as their training methods. Is Civil Engineering Education able to keep pace?

In this conference, this question will be answered addressing the following topics:

1. **New contents and capabilities:** Resilience, sustainability, BIM (Building Information Modelling), soft skills, automation, artificial intelligence, smart cities, UAV (Unmanned Aerial Vehicles).
2. **Methodology:** Student centered teaching methods, online learning, flip learning, active learning, PBL (Project Based Learning)
3. **The impact of educational policies:** quality management, quality control and accreditation agencies, links between teaching, research and practice

The conference will be organized by Escola de Camins (Department of Civil and Environmental Engineering) of the Universitat Politècnica de Catalunya (UPC BarcelonaTech), and EUCEET (European Civil Engineering Education and Training) Association.

Civil Engineering School of Barcelona
Technical University of Catalonia, BarcelonaTech
C / Jordi Girona 1-3, C2, 08034-Barcelona, Spain
Email: euceet2018@cimne.upc.edu
Web: congress.cimne.com/EUCEET2018

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

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

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

25-28 September 2018, Lausanne, Switzerland
https://seg2018.epfl.ch

The International Symposium on Energy Geotechnics (SEG) 2018 has been organized recognizing the strong need for shared knowledge in innovative and challenging applications on energy geotechnics. SEG-2018 aims to serve as a forum for promoting the exchange of ideas, practices and state-of-the-art on a broad range of topics in the area.

The upcoming edition of the symposium series, SEG-2018, will be held on the 25th-28th of September 2018 at Swiss Federal Institute of Technology in Lausanne (EPFL), with the Laboratory of Soil Mechanics (LMS) serving as the local organizing committee. Keynote lectures from the most prominent researchers and practitioners in the field, state-of-the-art lectures and technical sessions focusing on the task forces of TC-308 and discussion sessions for compiling the contributions of the day will be a part of SEG-2018.

Contributions on various topics related to the energy geotechnics field including carbon sequestration, energy geostructures, hydraulic fractured sediments, nuclear waste deposits and many more are encouraged in the scope of SEG-2018.

Topics

Research Fields:

- Carbon Sequestration
- Energy Geo-Storage & Geo-structures
- Urban Planning for Energy Geo-Systems
- Gas Hydrate Sediments
- Shallow & Deep Subsurface Geo-Thermal Systems
- Natural & Hydraulic Fractured Reservoirs
- Nuclear Waste Deposits
- Oil Sediments / Tailings
- Geotechnical Challenges of Energy Infra-Structures
- THMC Behavior of Geomaterials
- Unconventional Reservoirs
- Foundations for Floating Offshore Structures (offshore wind turbines, floating solar panels etc)
- And other topics related to energy geotechnics

Researchers working on these challenging topics are invited to present their most recent advances. Practitioners are invited to share their experience on various topics of energy geotechnics where presentations on case studies are strongly encouraged. Moreover, SEG-2018 puts an emphasis on discussing innovative ideas and highly encourages the presentation of patents and start-ups in the broad spectrum of energy geotechnics.

Technical Program:

The technical program consists of six keynote lectures, three feature lectures and a series of mini-symposia and technical sessions which will be given in parallel. Further, there will be a special session dedicated to the latest patents and budding start-ups in the field of energy geotechnics. This will allow participants to interact with the speakers and one another in order develop a more complete understanding of the day's material.

Beyond the core program, there are also some additional activities you may find interesting:

- Short course on the design of energy geostructures, Monday, September 24th (the day before the start of SEG 2018) – more info
- Visit of the Laboratory for Soil Mechanics, Tuesday, September 25th (before the start of the welcome reception)
- Visit to the Mont-Terri Underground Rock Laboratory, Saturday, September 29th(the day after the end of SEG 2018) – more info

Contacts seg2018@epfl.ch

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

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

www.c2rop.fr/symposium-rss-2018

The fourth edition of the international Symposium RSS (Rock Slope Stability) will be held in Chambéry, France, from 13th to 15th November 2018. The 2018 edition is again organised through the National Project C2ROP (Chutes de blocs, Risques et Ouvrages de Protection).

RSS 2018 is an international forum bringing together all actors of the academic and professional sectors over three days. The symposium is a place for sharing, networking and technical presentations.

Topics

- Site investigation and rockfall hazard modelling
- Monitoring techniques
- Rockfall trajectory analysis
- Risk management
- Protection structures
- Case studies

Contact

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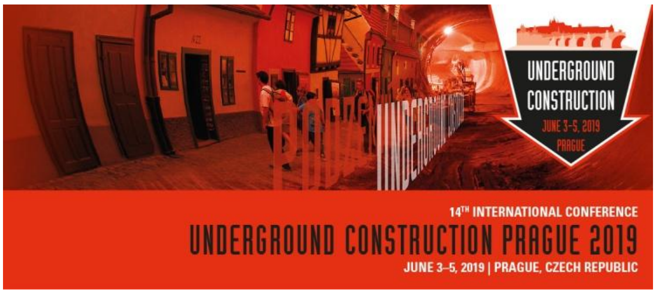
WTC2019 Tunnels and Underground Cities: Engineering and Innovation meet Archaeology, Architecture and Art and ITA - AITES General Assembly and World Tunnel Congress, 3-9 May 2019, Naples, Italy, www.wtc2019.com



14th international Conference
"Underground Construction Prague 2019"
3 to 5 June 2019, Prague, Czech Republic
www.ucprague.com

Dear Colleagues and Friends,

On behalf of the organisers of the International Conference **Underground Construction Prague** we would like to wish you good health, personal joy and professional success and satisfaction in the New Year.

The 14th international conference **Underground Construction Prague 2019** will be held in Prague **3–5 June 2019**.

The conference is endorsed by the International Tunnelling and Underground Space Association (ITA).

We are looking forward to your active participation and exchange of new information and experience.

Thematic Sessions:

1. Conventionally excavated tunnels
2. Mechanically excavated tunnels
3. Other underground structures, repositories, reconstructions and history
4. Geotechnical investigation and monitoring
5. Numerical modelling, BIM, research and development
6. Equipment, operational safety and maintenance

7. Risk management, contractual relationships and funding

CONTACTS

Czech Tunnelling Association ITA-AITES

Dr. Markéta Prušková, Dělnická 12, 170 00 Prague 7, Czech Republic
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Secretariat of the Preparatory Committee

SATRA, spol. s r. o., Sokolská 32, 120 00 Prague 2, Czech Republic
Phone: +420 296 337 181, fax: +420 296 337 189

Organising agency

GUARANT International spol. s r. o., Na Pankráci 17, 140 21 Prague 4, Czech Republic
Phone: +420 284 001 444, fax: +420 284 001 448, e-mail: ps2019@guarant.cz, website: www.guarant.com

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7 ICEGE 2019

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

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

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ISDCG 2019

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

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

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

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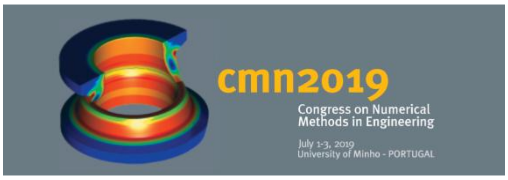

Congress on Numerical Methods in Engineering
July 1 - 3, 2019, Guimarães, Portugal
www.cmn2019.pt

The **Congress on Numerical Methods in Engineering (CMN 2019)** aims to be a forum for the discussion of relevant scientific, and technological developments in computational mechanics, numerical methods and engineering applications. **CMN 2019** is jointly organized by the Portuguese (**APMTAC**) and the Spanish (**SEMNI**) Associations and follows the previous congress editions of Madrid (2002), Lisbon (2004), Granada (2005), Porto (2007), Barcelona (2009), Coimbra (2011), Bilbao (2013), Lisbon (2015) and Valencia (2017).

The scientific program will comprise plenary lectures from leading researchers and will be structured in thematic sessions in different research fields. The congress is open to professionals, researchers, educators, students and everyone else interested in numerical methods. The objective is to make the congress the best forum for dissemination of the latest scientific and technical developments and for exchange of new ideas in emerging topics.

Topics

The main topics of the congress include:

- Acoustics and Vibration
- Aerodynamics
- Boundary Elements
- Chemical Engineering
- Coastal & Marine Engineering
- Composite Materials
- Computational Biology
- Computational Geometry
- Concrete Structures
- Contact Mechanics
- Decision Support Systems
- Earthquake Engineering
- Electromagnetism
- Environmental Engineering
- Estimation Error
- Finite Elements
- Fluid Mechanics
- Frictional Materials
- Genetic Algorithms
- Geotechnics
- Heat & Mass Transfer

- Historical Constructions
- Image Processing/Visualization
- Material Fracture & Collapse
- Mechanics of Soils and Rocks
- Medical Informatics
- Mesh Generation/Refinement
- Meshless Methods
- Micromechanics
- Multibody Dynamics
- Multi-Scale Methods
- Nanomechanics
- Non-Newtonian Fluids
- Object Oriented Programming
- Optimization
- Parallel Computing
- Plastic Forming
- Plasticity & Viscoplasticity
- Probabilistic/Stochastic Meth
- Signal Processing/Analysis
- Simulation of Fireworks
- Soft Computing
- Solid Mechanics
- Steel & Composite Structures
- Structural Dynamics
- Structural Identification
- Structural Stability

Thematic Sessions

Thematic sessions are welcome in the topics of the congress. Proposals for these sessions should be sent to the organization before May 25, 2018 (pbl@civil.uminho.pt) including a title, a brief abstract, organizers (ideally a minimum of one from APMTAC and SEMNI). Ideally, these should have a minimum of 7 contributions.

Secretariat Contact

For additional information, please contact the secretariat of the congress, Ms. Lara Leite

CMN2019, Universidade do Minho, Departamento de Engenharia Civil, 4800-058 Guimarães - Portugal
Email: cmn2019@civil.uminho.pt
Telephone: +351 253 510 748
Fax: +351 253 510 217

The 17th European Conference on Soil Mechanics and Geotechnical Engineering

1st - 6th September 2019, Reykjavik Iceland

www.ecsmge-2019.com

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

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

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

The main topics are divided in following six main categories and 22 subcategories:

A: Modelling and experimental assessment of geomaterials

B: Geotechnical construction and soil improvement

C: Geohazards, earthquakes and mitigation

D: Environment, water and energy

E: Historical heritage preservation

F: Special and specific Issues

A: Modelling and experimental assessment of geomaterials

A.1. Investigation by laboratory tests

Equipment, apparatus, procedures, interpretation and parameters representativeness and reliability.

A.2. Investigation by in situ tests

Equipment, apparatus, Intrusive tests, geo-physical tests, procedures, validation, interpretation and parameter representativeness and reliability.

A.3. Physical modelling and large scale tests

Model tests, centrifuge tests, load tests, well tests, equipment, apparatus, procedures, validation, interpretation and parameter representativeness and reliability.

A.4. Theoretical modelling

Analytical, numerical, continuous approach, discrete element approaches, constitutive laws, applicability, reliability, effectiveness and validation.

A.5. Design parameter

Identification, selection, limit states, regulations, rules and guidelines.

Identification, selection, limit states, regulations, rules and guidelines.

B: Geotechnical construction and soil improvement

B1. Foundations, excavations and earth retaining structure

Shallow and deep foundations, retaining and diaphragms wall, basements, deep excavations, tunnels and temporary works.

B.2. Slopes stabilization and earthworks

Cut slopes, earthworks and embankments, dams, tailings dams, dykes and levees, slope failure repair and remediation.

B.3. Ground reinforcement and ground improvement

Soil reinforcement, ground anchors, geosynthetics, grouting, densification, thermal treatment (artificial ground freezing), bio-chemical geotechnics and other forms of ground treatment.

B.4. Structures and infrastructure

Roads, highways and railways; bridges; tunnels; canals and waterways, power lines and pipelines, mega cities and smart cities.

B.5. Near shore and offshore structures and the marine environment

C: Geohazards, earthquakes and mitigation

C.1. Landslides and other solid flows

Slow earth and rock movements, natural slopes, debris flows, mudflows, rock falls, snow and ice avalanches, volcanoes, hazard and risk evaluation and mapping, disaster response and recovery, effects of climate and associated global changes.

C.2. Earthquake engineering and soil dynamics

Identifications and characterization of seismic areas and dynamic soil properties, liquefaction, hazard and risk mapping, disaster response and recovery.

C.3. Floods, erosion and scours

Effects of climate and associated global change, river and sea floods, tsunami, sea level change, subsidence, scour, sinkholes, cavities by anthropomorphically-induced events.

C.4. Hazard and risk management

Vulnerability and fragility of buidlings and infrastructure to hazards and hazard and risk management and mitigation.

D: Environment, water and energy

D.1. Environmental geotechnics

Waste management, landfill design, reused/recycled materials, sustainability, contaminated land, active and passive barriers for contaminant control, coupled flow of mass and energy in fine grained soils, environmental risk analysis.

D.2. Groundwater and hydrology

Groundwater modelling, groundwater abstraction and recharge, hydraulic barriers, groundwater treatment, dewatering, changes in groundwater regime.

D.3. Energy, incl. geothermal energy

Geothermal energy, heat ground source, heat pumps, energy piles, tunnel linings and other underground constructions for energy storage and optimized exploitation, wind farms and wind turbines, carbon dioxide sequestration, tidal and wave power generation.

E: Historical heritage preservation

E.1. Investigation, characterization and testing

Interactions and cooperation among the experts of the different skills, soil, foundation and structure investigation and characterization, modelling of soil, foundation and structure interactions.

E.2. Case histories

Historic buildings, monuments, retrofitting, reinforcement and reuse, archaeology.

F: Special and specific Issues

F.1. Problematic materials and environments

Glacigenic and periglacial materials, peats, aeolian deposits, natural muds and muds from industrial waste, collapsing soils, swelling soils, weak rocks, permafrost and loss of permafrost, and tropical soils and highly weathered materials, unsaturated soils.

F.2. Developments and innovations in geotechnical engineering, education and practice

Codes and standards (e.g. EC7 and EC8), BIM, GIS, smart instrumentation, engineering and project risk assessment, management and mitigation, stakeholder collaboration, interactive design (observational method), safety and serviceability, environmental impact assessment, educational development, retraining and e-learning.

Flood barrages, sea breakwater, piers, estuarine airports, ports, dredgin

F.3. Forensic geotechnical engineering

Geotechnical failures and criminology including case histories.

Conference secretariat

ATHYGLI CONFERENCES

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

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

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

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

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

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

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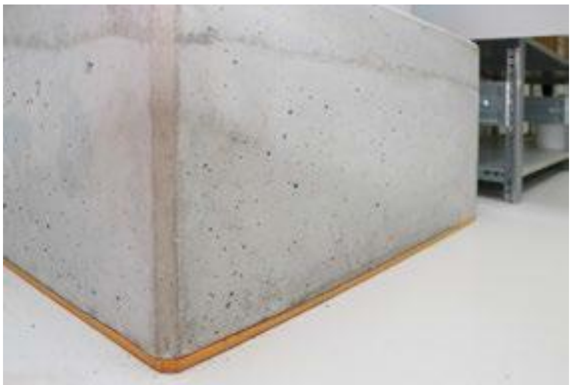
Phone: +358-(0)50 312 4775
Email: leena.korkiala-tanttu@aalto.fi

ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

"Proctorgeräte" on new foundations
A scientific solution for a structural engineering problem



Following its move to the EUREF campus in Berlin Schöneberg, the Eastern Germany Region of the Environment, Geotechnics & Survey Service Unit, has also put a new geotechnics laboratory into operation. Upon first using the two "Proctorgeräte" (mechanical compactors) installed there, however, it became immediately clear that the foundation and insulation panels for the vibrations caused during operation were not having enough of a dampening effect, to the extent that the vibrations could be noticed on the 3rd floor.

Together with the Austrian company Getzner Werkstoffe GmbH, a new solution was developed in which a sub-ballast mat is used as a dampening element. On top of this, a concrete foundation has been placed that has been optimally weighted, reinforced and sized to ensure the lowest possible own natural frequency of each mechanical compactor. Since then, it is quiet again in House 5.

In the mechanical compactor, a soil sample is compacted by way of a varying number of blows of the drop weight until it reaches the Proctor density, which is used as a reference density for the respective soil with comparative measurements.

(Dieter Jung, DB Engineering & Consulting, Geotechnics, Berlin / E&C Inside | N° 14 | June 2017, Intranet: https://intranet.db-ec.de | Internet: www.db-engineering-consulting.com)

Shoring failure at unknown location due monsoon rains

https://www.youtube.com/watch?v=m7nvmb4ExSY&feature=share

Published on Jun 27, 2017

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ

Japan's earthquakes and tectonic setting

Japan has more measurable earthquakes than any other country and has over 100 active volcanoes. These both result from Japan being wedged among four major tectonic plates.

The tectonics are complicated, but in this animation, IRIS attempted to look at the basic mechanics of the region as they focused on two famous earthquakes: the 1995 Kobe (Great Hanshin) earthquake and the 2011 Tohoku-Oki earthquake. It is necessarily simplified to depict basic processes.

https://www.youtube.com/watch?time_continue=18&v=5BHnf1wGD9w

Although there are many published fault-displacement models derived from fitting different sets of observations (teleseismic waveforms, tsunami heights, GPS displacements, seafloor deformation, etc.), there is considerable disagreement between those fault-displacement models.

For a variety of reasons, the animation group decided to illustrate the fault-displacement model of Jiang and Simons, 2016, Journal of Geophysical research, 10.1002/2016JB013760.

Written & directed by Dr. Robert F. Butler, University of Portland
Animation & graphics by Jenda Johnson, Earth Sciences Animated
Narrated by Wendy Bohon, Informal Education Specialist, IRIS

Scientific review:

Dr. Hiroyuki Tsutsumi, Doshisha University (堤 浩之, 同志社大)
Dr. Chris Goldfinger, Oregon State University
Dr. Lori Dengler, Humboldt State University

(THE WATCHERS, June 15, 2017, https://watchers.news/2017/06/15/japan-earthquakes-tectonic-setting)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

Why Roman concrete still stands strong while modern version decays

Scientists have cracked the secret to Roman water-based structures' strength – and findings could help today's builders

Scientist Marie Jackson has said Swansea lagoon's seawall should be built using Roman concrete. Photograph: Tidal Lagoon Power/PA

Their structures are still standing more than 1,500 years after the last centurion snuffed it: now the Romans' secret of durable marine concrete has finally been cracked.

The Roman recipe – a mix of volcanic ash, lime (calcium oxide), seawater and lumps of volcanic rock – held together piers, breakwaters and harbours. Moreover, in contrast to modern materials, the ancient water-based structures became stronger over time.

Scientists say this is the result of seawater reacting with the volcanic material in the cement and creating new minerals that reinforced the concrete.

"They spent a tremendous amount of work [on developing] this – they were very, very intelligent people," said Marie Jackson, a geologist at the University of Utah and co-author of a study into Roman structures.

As the authors note, the Romans were aware of the virtues of their concrete, with Pliny the Elder waxing lyrical in his Natural History that it is "impregnable to the waves and every day stronger".

Now, they say, they've worked out why. Writing in the journal American Mineralogist, Jackson and colleagues describe how they analysed concrete cores from Roman piers, breakwaters and harbours.

Previous work had revealed lime particles within the cores that surprisingly contained the mineral aluminous tobermorite – a rare substance that is hard to make.

The mineral, said Jackson, formed early in the history of the concrete, as the lime, seawater and volcanic ash of the mortar reacted together in a way that generated heat.

But now Jackson and the team have made another discovery. "I went back to the concrete and found abundant tobermorite growing through the fabric of the concrete, often in association with phillipsite [another mineral]," she said.

She said this revealed another process that was also at play. Over time, seawater that seeped through the concrete dissolved the volcanic crystals and glasses, with aluminous tobermorite and phillipsite crystallising in their place.

These minerals, say the authors, helped to reinforce the concrete, preventing cracks from growing, with structures becoming stronger over time as the minerals grew.

By contrast, modern concrete, based on Portland cement, is not supposed to change after it hardens – meaning any reactions with the material cause damage.

Jackson said: "I think [the research] opens up a completely new perspective for how concrete can be made – that what we consider corrosion processes can actually produce extremely beneficial mineral cement and lead to continued resilience, in fact, enhanced perhaps resilience over time."

The findings offer clues for a concrete recipe that does not rely on the high temperatures and carbon dioxide production of modern cement, but also providing a blueprint for a durable construction material for use in marine environments. Jackson has previously argued Roman concrete should be used to build the seawall for the Swansea lagoon.

"There's many applications but further work is needed to create those mixes. We've started but there is a lot of fine-tuning that needs to happen," said Jackson. "The challenge is to develop methods that use common volcanic products – and that is actually what we are doing right now."

(Nicola Davis / The Guardian, Tue 4 Jul 2017, https://www.theguardian.com/science/2017/jul/04/why-roman-concrete-still-stands-strong-while-modern-version-decays)

Phillipsite and Al-tobermorite mineral cements produced through low-temperature water-rock reactions in Roman marine concrete

Marie D. Jackson, Sean R. Mulcahy, Heng Chen, Yao Li, Qinfei Li, Piergiulio Cappelletti and Hans-Rudolf Wenk

Abstract

Pozzolanic reaction of volcanic ash with hydrated lime is thought to dominate the cementing fabric and durability of 2000-year-old Roman harbor concrete. Pliny the Elder, however, in first century CE emphasized rock-like cementitious processes involving volcanic ash (*pulvis*) "that as soon as it comes into contact with the waves of the sea and is submerged becomes a single stone mass (*fierem unum lapidem*), impregnable to the waves and every day stronger" (*Naturalis Historia* 35.166). Pozzolanic crystallization of Al-tobermorite, a rare, hydrothermal, calcium-silicate-hydrate mineral with cation exchange capabilities, has been previously recognized in relict lime clasts of the concrete. Synchrotron-based X-ray microdiffraction maps of cementitious microstructures in *Baianus Sinus* and *Portus Neronis* submarine breakwaters and a *Portus Cosanus* subaerial pier now reveal that Al-tobermorite also occurs in the leached perimeters of feldspar fragments, zeolitized pumice vesicles, and *in situ* phillipsite fabrics in relict pores. Production of alkaline pore fluids through dissolution-precipitation, cation-exchange and/or carbonation reactions with Campi Flegrei ash components, similar to processes in altered trachytic and basaltic tuffs, created multiple pathways to post-pozzolanic phillipsite and Al-tobermorite crystallization at ambient seawater and surface temperatures. Long-term chemical resilience of the concrete evidently relied on wa-

ter-rock interactions, as Pliny the Elder inferred. Raman spectroscopic analyses of *Baianus Sinus* Al-tobermorite in diverse microstructural environments indicate a cross-linked structure with Al^{3+} substitution for Si^{4+} in Q^3 tetrahedral sites, and suggest coupled $[Al^{3+}+Na^{+}]$ substitution and potential for cation exchange. The mineral fabrics provide a geoarchaeological prototype for developing cementitious processes through low-temperature rock-fluid interactions, subsequent to an initial phase of reaction with lime that defines the activity of natural pozzolans. These processes have relevance to carbonation reactions in storage reservoirs for CO_2 in pyroclastic rocks, production of alkali-activated mineral cements in maritime concretes, and regenerative cementitious resilience in waste encapsulations using natural volcanic pozzolans.

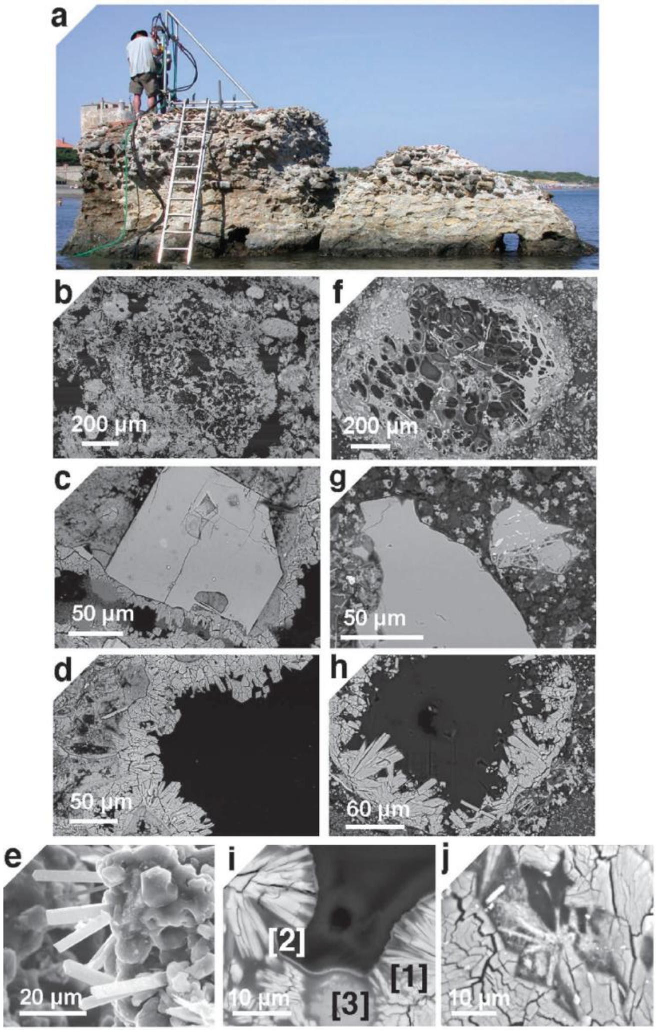


Figure 1. Authigenic mineral textures in tuff deposits and Roman marine mortar. Scanning electron microscopy back-scattered electron (SEM-BSE) images. (**a**) *Portus Cosanus* pier, Orbetello, Italy (credit, J.P. Oleson) (Fig. 2). (**b**) Bacoli tuff (BT), pumice clast. (**c**and **d**) Neapolitan Yellow Tuff (NYT), dissolving alkali feldspar, phillipsite, and chabazite textures. (**e**) Surtsey tuff, Iceland 1979 drill core, dissolving phillipsite and associated Al-tobermorite, 37.0 m, 100 °C (credit, J.G. Moore). (**f**) *Portus Cosanus*, pumice clast with dissolved glass. (**g**) *Portus Neronis*, Anzio, Italy, dissolving alkali feldspar (see also Fig. 5). (**h**) *Portus Cosanus*, phillipsite textures. (**i**) *Portus Cosanus*, dissolving Campi Flegrei phillipsite [1], pozzolanic C-A-S-H binder [2] and Al-tobermorite [3] (see Fig. 7i for X-ray microdiffraction patterns). (**j**) *Portus Baianus*, Pozzuoli, Italy, dissolving *in situ* phillipsite and associated Al-tobermorite (Fig. 9).

Figure 2. Ancient Roman concrete harbors and ROMACONS project drill sites, green circles: 1 = *Portus Cosanus*, 2 = *Portus Traianus*, 3 = *Portus Neronis*, 4 = *Baianus Sinus*. Volcanic districts, red triangles (after Jackson et al. 2013a).

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Appendix Table 1

Roman texts describing the geologic materials and cementitious processes of marine concrete, translations (Oleson 2014)

	English Translation	Interpretation
Vitruvius 30-22 BCE *de Architectura*2. 6.1	There is a kind of powdery earth (*pulvis*) that by its nature produces wonderful results. It occurs in the neighborhood of Baiae and the territory of the municipalities around Mount Vesuvius. This material, when mixed with lime and rubble (*calce et caemento*) not only furnishes strength to other buildings, but also, when breakwaters (*moles*) are built in the sea, they set underwater... Thus, when the-	Hydration of lime and pumiceous volcanic ash from the Campi Flegrei (and Vesuvius) volcanic districts (Fig. 2) with seawater created pozzolanic reactions that produce cementitious hydrates, mainly C-A-S-H, and rapid solidification of massive concrete structures that resisted the erosive action of seawater and the force of impact of storm waves in the marine environment.

	English Translation	Interpretation
	se three substances (pumiceous ash (*pulvis*), lime (*calx*), and tuff (*tofus*)) formed in a similar manner by the strength of fire are brought together in one mixture, and suddenly they are put into contact with [sea-] water, they cohere into a single mass, quickly solidifying, hardened by the moisture, and neither the effect of the waves nor the effect of water can dissolve them.	
Vitruvius 30-22 BCE *de Architectura*2. 6.4	Therefore, when dissimilar and incompatible materials [lime (*calx*), pumiceous ash (*pulvis*), and tuff (*tofus*) are taken and mixed in a moist environment the urgent need of moisture suddenly satiated by [sea-] water seethes with the latent heat in these substances and causes them to gather into a unified mass and gain solidity quickly.	Exothermic heat evolved from the production of C-A-S-H binder through pozzolanic reaction of lime, pumiceous ash, and seawater led to rapid solidification of the marine concrete.
Strabo 64/63 BCE-c.24 CE *Geographica*5.4.6	Puteoli has become a very great emporium because it has an artificially constructed harbor, something made possible by the natural qualities of the local sand (*ámmos*), which is well-suited to the lime and	In the decades following Vitruvius' descriptions of pozzolanic reaction in the marine concrete, pumiceous volcanic ash shipped from the harbor at Puteoli became a req-
	takes a firm set and solidity. Therefore, by mixing the sand-ash (*ammokonía*) with the lime, they can run moles out into the sea and in this way make the exposed shore into a protected bay, so that the largest cargo ships can anchor there safely.	uisite component of maritime harbor construction.
Seneca 4 BCE-65 CE*Quaestiones Naturales* 3.20.3-4	The water is adulterated and throws a sediment (*limus*) of such a nature that it cements (*adglutinet*) and hardens objects. Just as the [volcanic ash] *Puteolanus pulvis* becomes rock (*saxum est*) if it touches water so, by contrast, if this water touches something solid it clings to it and forms concretions.	Geologic processes for calcium carbonate cements in the Hebrus River, Thrace, and in travertine deposits near Rome, are compared with hydration of *pulvis* ash to form tuff.
Pliny the Elder 23-79 CE *Naturalis Historia*35.166	For who could marvel enough that on the hills of Puteoli there exists a dust (*pulvis*)'so named because it is the most insignificant part of the Earth' that, as soon as it comes into contact with the waves of the sea and is submerged, becomes a single stone mass, impregnable to the waves and every day stronger...	A geologic analog to explain rock-like cohesion in marine concrete that improves over time calls upon the hydration processes through which *pulvis* ash cements itself to form tuff.

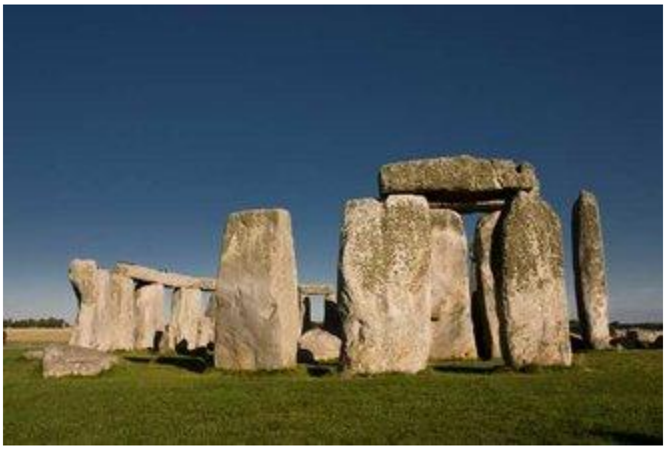
Notes: Increasing complexity in Roman construction durability and architectural design through invention, technology transfer, and competitive selection is described explicitly by Vitruvius in *de Architectura* (2.1.2, 2.1.7). Accelerated late Republican accelerated late Republican era innovations in construction engineering produced the resilient and rock-like concrete structures (Jackson and Kosso 2013). Marine concrete technologies fell into disuse about 4th CCE (Brandon et al. 2014).

(American Mineralogist (2017) 102 (7): 1435-1450. DOI: https://doi.org/10.2138/am-2017-5993CCBY, Published: July 01, 2017,
https://pubs.geoscienceworld.org/msa/ammin/article/102/7/1435-1450/353606)

The 25 Most Mysterious Archaeological Finds on Earth

Introduction

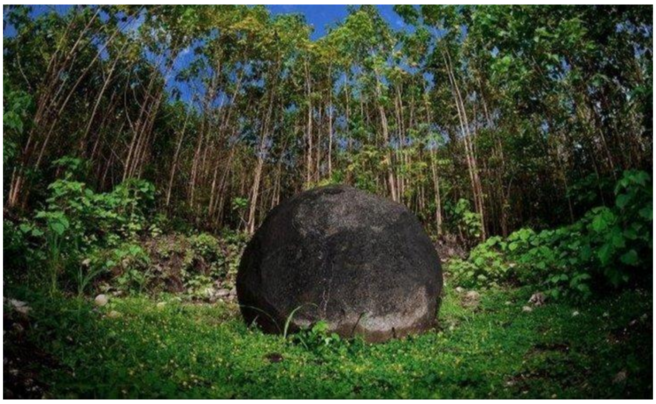
Puzzling ancient finds have a way of captivating the public, perhaps because it's just too easy to dream up interesting explanations for how and why things exist.



These 25 archaeological discoveries have left people in awe — and left scientists scratching their heads — year after year.

Stone spheres in Costa Rica

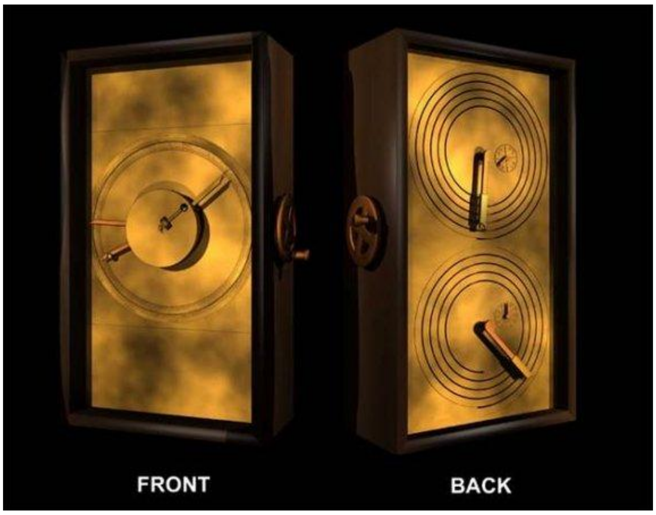
Giant stone spheres — some dating as far back as A.D. 600 — pepper the Diquis Delta of southern Costa Rica. Known locally as Las Bolas ("The Balls"), these monuments were the works of a Pre-Colombian civilization, and most are made from gabbro, a rock that forms from molten magma. The people who carved the stones into their perfectly spherical shapes likely did so using other small stones, according to archaeologists who study the ancient rocks.



Many non-experts have speculated that the so-called Diquis Spheres were used for astronomical purposes, while others think they may have pointed the way to significant places. The truth is that no one knows for sure. The Chibchan people who once populated Costa Rica and other parts of Central America vanished in the wake of the Spanish conquest, and the purpose of the spheres vanished with them, John W. Hoopes, an anthropologist at the University of Kansas, told JSTOR Daily in January 2016.

Antikythera mechanism

Like something from a fantastical treasure movie, the discovery of the Antikythera Mechanism remains a major archaeological head-scratcher.

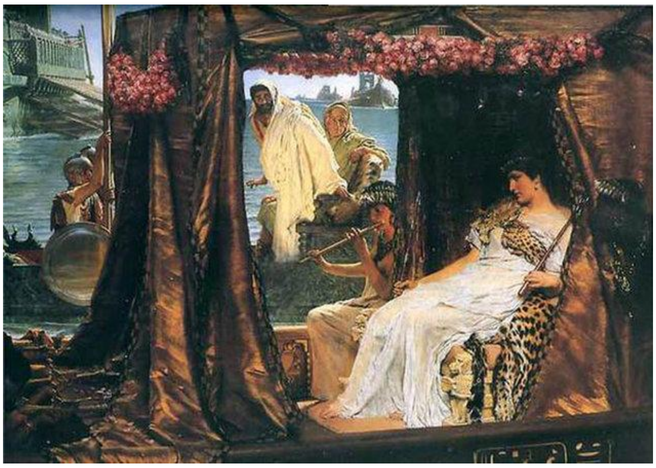


Found in the sunken wreckage of a Greek cargo ship that is at least 2,000 years old, the circular bronze artifact contains a maze of interlocking gears and mysterious characters etched all over its exposed faces. Originally thought to be a kind of navigational astrolabe, archaeologists continue to uncover its uses and now know that it was, at the very least, a highly intricate astronomical calendar.

It is still the most sophisticated device ever found from that period, preceding the next appearance of similar devices by 1,000 years.

Cleopatra's tomb

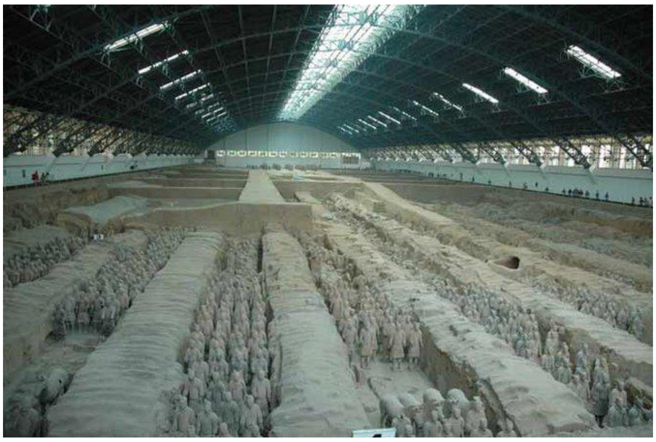
Cleopatra VII was the last of a series of rulers called the Ptolemies who ruled Egypt between 305 and 30 B.C. Much is known about her intelligence, beauty and romantic relationships (she had children with both Julius Caesar and Mark Antony), but one fact about Cleopatra is still shrouded in mystery — her burial place.



Cleopatra and Antony both committed suicide after their former ally, Octavian, defeated them at the Battle of Actium in 31 B.C. The two were buried together at a site that the writer Plutarch (A.D. 45-120) described as a "lofty and beautiful" monument, located near a temple of the Egyptian goddess Isis. But exactly where this tomb is located remains a mystery. If anyone ever finds the lovers' tomb, there's a chance it might be empty, as grave robbery was not uncommon in ancient times, according to archaeologists.

Qin Shi Huang's tomb

In 1974, farmers in China's Shaanxi province accidentally unearthed one of the biggest archaeological finds of the 20th century — the life-size terracotta army of Emperor Qin Shi Huang (259 B.C. – 210 B.C.).



The intricately carved figures aren't a mystery: Historians know that the clay army was created to defend China's first emperor in the afterlife. What isn't known, however, is where exactly the emperor is buried or what treasures his burial chamber might contain. [See Photos of the Ancient Terracotta Warriors]

A pyramid-shaped mausoleum is located about a mile to the northeast of where the terracotta army was discovered. However, no one has actually entered the mausoleum that holds Qin Shi Huang's remains.

The first emperor's final resting place is the most opulent tomb ever constructed in China, according to ancient documents describing its construction. An underground palace, complete with a surrounding "kingdom," the mausoleum is made up of a network of caves and even included a state-of the-art drainage system. Whether archaeologists will ever have the technology they need to safely excavate the tomb (which also happens to contain extremely high levels of mercury) remains a mystery, as do the many treasures that lay inside.

Atlantis

The lost city of Atlantis has been discovered in the Bahamas, the Greek Islands, Cuba, and even Japan if every claim was to be believed.

First described by the ancient Greek historian Plato in 360 B.C., the mythological island was supposedly a great naval power before sinking into the sea over 10,000 years ago in a catastrophic event.

Archaeologists debate the actual historical existence of the island as well as its most plausible location if it ever actually existed among the many sunken ruins discovered around the world. But even without definitive proof, Atlantis continues to engage the popular imagination like few other archaeological mysteries out there.

Stonehenge

Sprucing up an otherwise docile English field, the prehistoric monument commonly known as Stonehenge is one of the world's most famous landmarks.

The ring of megalithic stones was built approximately 4,000 years ago and was an impressive feat for the primitive people who constructed it but that's about all archaeologists know for sure. None of the theories on the original purpose of Stonehenge, which range from an astronomical observatory to a religious temple of healing, has ever been, well, set in stone.

Ancient animal traps

Low stone walls crisscrossing the deserts of Israel, Egypt and Jordan have puzzled archaeologists since their discovery by pilots in the early 20th century.

The chain of lines some up to 40 miles (64 kilometers) long and nicknamed "kites" by scientists for their appearance from the air date to 300 B.C., but were abandoned long ago.

The mystery might be somewhat clearer thanks to a recent study claiming that the purpose of the kites was to funnel wild animals toward a small pit, where they could easily be killed in large numbers. This efficient system suggests that local hunters knew more about the behavior of local fauna than previously thought.

Nazca lines

From the ground, the Nazca Lines of Peru are nothing spectacular. However, seen from the air, from which they were first spotted by commercial aircraft in the 1920s and 30s, they are staggering.

Archaeologists agree the enormous shapes there are hundreds of them, ranging from geometric lines to complicated depictions of animals, plants and imaginary figures were made over 2,000 years ago by people of the pre-Inca Nazca culture, who simply removed the red surface pebbles to reveal the lighter earth below in designs of their choice.

Just why they did it remains enigmatic, prompting conspiracy theorists to float ideas about alien landings and ancient astrology. The lines were more likely to have been a ritual communication method with the Nazca's deities, say archaeologists.

The Great Pyramids

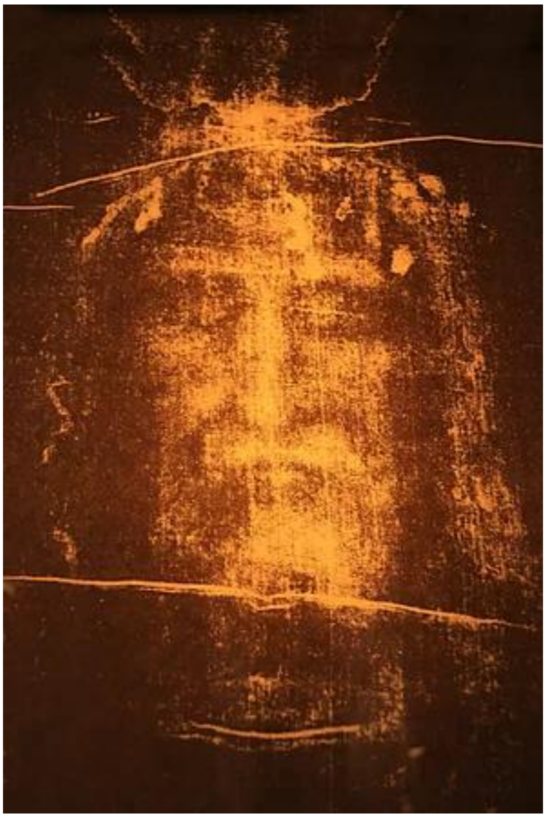
Even the information that archaeologists do know about the Great Pyramids of Egypt is enormously fascinating, to say nothing about what still might be uncovered.

Built almost 5,000 years ago in what is now Cairo, the three-pyramid complex with the largest, Khufu, dominating the site is a testament to the ancient Egyptians' reverence for their Pharaohs and the intricacies of their belief in the afterlife.

Archaeologists are still discovering new tunnels and shafts built within the pyramids, and are still searching for clues on who built the great monuments, how and why, even today.

Shroud of Turin

Perhaps no archaeological discovery is more debated than the enigmatic Shroud of Turin, which many believe to be the burial shroud of Jesus Christ. This long piece of twill cloth bears traces of blood, as well as the darkened imprint of a man's body.



The Catholic Church officially recorded the existence of the shroud in A.D. 1353, which is when the cloth showed up in a church in Lirey, France. But the legend of the shroud dates back to A.D. 30 or 33. According to that legend, the shroud was transported from Judea (now southern Palestine) to Edessa, Turkey, and later to Constantinople (now called Istanbul). When crusaders sacked Constantinople in A.D. 1204, the cloth was moved to Athens, Greece, where it was allegedly held until A.D. 1225.

It wasn't until the 1980s that researchers got their hands on the cloth to try to determine its true age using radiocarbon dating. They determined that the alleged burial cloth of Jesus was actually created between A.D. 1260 and A.D. 1390. In other words, the scientists determined that the cloth is most likely a medieval forgery. However, critics of this research argue that the scientists may have dated newer portions of the shroud that were stitched together centuries after Jesus' death, which would explain why the shroud seems "newer" than it really is.

Gobekli Tepe

Humans first settled into permanents towns, farmed and then built temples, in that order, starting in 8,000 B.C. Or did they?

An amazing archaeological discovery made in 1994 at Gobekli Tepe, a rural area of Turkey, has blown that hypothesis apart, prompting new questions about the evolution of civilization.

Containing multiple rings of huge stone pillars carved with scenes of animals and dating to the 10th millennium B.C., Gobekli Tepe is considered the world's oldest place of worship. Yet evidence also suggests the people who built it were semi-nomadic hunters, likely unaware of agriculture, which followed in the area only five centuries later. Because of Gobekli Tepe, archaeologists now have to ask which came first. Did building projects like this lead to settlement, and not vice-versa, as always thought?

The Copper Scroll treasure

Here's one archaeological mystery that we'd really like to solve: An ancient copper scroll discoveredat the site of Qumran in 1952 might describe a massive amount of hidden gold and silver, but no one knows where that treasure might be or if it even exists.

The copper scroll was found alongside the Dead Sea Scrolls in what is now the West Bank in the Palestinian territories. It dates back nearly 2,000 years to a time when the Roman Empire controlled the Qumran settlement. Researchers believe that the scroll might describe a treasure that was hidden by locals to keep it out of the hands of Roman forces during the area's frequent revolts against the empire.

King Tut's death

Few archaeological mysteries conjure up as much excitement as this one: the mysterious mummy of the Egyptian boy pharaoh Tutankhamun.

King Tut's tomb was unearthed in 1922 by British Egyptologist Howard Carter, and tales of a "pharaoh's curse" that kills those who come near the tomb have circulated ever since. But the real mysteries of King Tut's tomb are even more interesting than any curse. Archaeologists believe that the boy king died unexpectedly, perhaps from an infection or from injuries sustained in a chariot accident. His untimely death may help to explain the strange condition that his mummy was in when it was discovered.

King Tut appears to have caught fire after his body was mummified and his tomb sealed. Experts who have studied the mummy believe that King Tut's linen wrappings, which were soaked in flammable embalming oils, may have reacted with oxygen in the air to start a chain reaction that ignited the king's corpse, "cooking" it at about 390 degrees Fahrenheit (200 degrees Celsius).

A rushed burial was likely behind the botched embalming job that caused the fire. But the hasty burial of this royal figure also gives rise to another mystery: It's possible that King Tut's tomb was originally built for someone else, and there may be other, undiscovered mummies buried in the same tomb.

The Ark of the Covenant

The Ark of the Covenant is a gold-encrusted wooden chest that contains the stone tablets of the 10 commandments, according to the Book of Exodus. In ancient times, this holy box was kept in the First Temple, a Jewish place of worship in Jerusalem. But the First Temple was destroyed in 587 B.C. by a Babylonian army led by King Nebuchadnezzar II, according to the Hebrew Bible. No one knows for sure what became of the ark, though since its disappearance, many people (both real and fictional) have gone looking for it.

So far, no one has actually found the holy relic (apart from Indiana Jones, of course). Some ancient reports say that the ark made its way to Babylon after Nebuchadnezzar's sack of the city. Others say that the ark was buried somewhere in Jerusalem, or that it was destroyed along with the First Temple. Modern reports hint that the ark resides in a monastery in Ethiopia.

And a recently translated ancient Hebrew text suggests that the Ark of the Covenant will simply reveal itself, though not "until the day of the coming of the Messiah son of David."

Voynich manuscript

One of the most talked about books of the 20th century was an ancient text that no one could read. Discovered by an antique bookseller in 1912, the Voynich manuscript is a 250-page book written in an unknown alphabet and illustrated with a range of images, from female nudes to medicinal herbs and Zodiac signs.

The book, which is currently housed at Yale University's Beinecke Rare Book & Manuscript Library, dates back some 600 years and was likely written in Central Europe, according to researchers. While some scholars believe the book is simply a Renaissance-era hoax full of unintelligible words, there are some who think the book's text is written in an unknown language. Others believe the book lays out some kind of code that has yet to be cracked.

Stephen Bax, a professor of applied linguistics at the University of Bedfordshire in England, claimed to have deciphered 14 of the Voynich manuscript's characters in February 2014. The book is most likely a treatise on nature, written in a Near Eastern or Asian language, according to Bax.

The Hobbits

Some scientific discoveries are truly stranger than fiction. Case in point: the 2003 discovery of hobbits on the remote Indonesian island of Flores. No, scientists didn't stumble upon a real-world version of the Shire, but they did uncover the bones of the petite ancient hominin *Homo floresiensis*, which they quickly dubbed "the Hobbit."

The first *H.floresiensis* skeleton ever discovered belonged to a 3.5-foot-tall (1.06 meters), 30-year-old adult female. At first, researchers believed the diminutive bones may have belonged to a human with microcephalia, a condition characterized by a small head and short stature. But later discoveries of similarly sized skeletons suggested that the

Hobbit isn't just a tiny human — it's its own species. Yet, *H.floresiensis'* exact place in the family tree of hominins (human ancestors) is still a mystery.

Disappearance of the Sanxingdui

Not every perplexing archaeological discovery is made by a seasoned archaeologist. In 1929, a man repairing a sewage ditch in China's Sichuan province uncovered a treasure trove of jade and stone artifacts. These treasures found their way into the hands of private collectors, and in 1986, archaeologists working in the area unearthed two more pits full of Bronze Age treasures, including jade, elephant tusks and bronze sculptures.

But who created these hidden wonders? Researchers now believe that members of the Sanxingdui civilization — a culture that collapsed between 3,000 and 2,800 years ago — made the artifacts. Archaeologists now know that the Sanxingdui once inhabited a walled city along the banks of the Minjiang River. But why they left this city, and why they buried so many artifacts in pits before absconding, is the source of much speculation among researchers. In 2014, researchers presented one idea at the meeting of the American Geophysical Union in San Francisco, suggesting that an earthquake 3,000 years ago may have rerouted the city's river, causing the inhabitants to move.

Noah's Ark

Some things are so good you just want to discover them again and again — like Noah's Ark, for example. The Biblical boat has been discovered many times by many people … or has it?

For centuries, amateur archaeologists from around the world have claimed to find evidence of the ark on and around Mount Ararat in Turkey, which is where the boat came to rest, according to the Book of Genesis. But some researchers doubt whether Noah's giant ark was ever built. Like Atlantis, Noah's Ark is an archaeological mystery that will continue to be solved, again and again, even though it might not exist.

The lost Maya

How does a civilization that thrived for the better part of six centuries just disappear? That's a mystery that archaeologists working in southern Mexico and northern Central America have been trying to solve for decades.

Around A.D. 900, the flourishing Mayan civilization collapsed, but the reasons for this downfall are unclear. Scientific studies suggest that drought may have played a key role in the fall of the Maya. As the Maya cleared forests to make way for bigger cities and farmland, they may have inadvertently worsened the frequent droughts that were their undoing, according to a study published in the journal Science in 2012.

Other researchers speculate that soil degradation and declining prey populations (white-tailed deer, in particular) contributed to the end of the Maya. Still others experts note that shifting trade routes, as well as internal political conflicts likely hurried the demise of the once great empire.

The Khatt Shebib

You might think that a 93-mile-long (150 kilometers) stone wall would have a very obvious purpose, but that is not the case for the Khatt Shebib. This mystery wall in Jordan was first reported in 1948, and archaeologists still aren't sure why it was built, when it was built or who built it.

The wall runs north-northeast to south-southwest and contains sections where two walls run side by side, as well as sections where the wall branches off. Though today the wall is in ruins, in its heyday, most of it would have stood about 3.3 feet (1 meter) high and just 1.6 feet (0.5 meters) wide; it's unlikely that the Khatt Shebib was built to keep out invading armies. However, it may have been constructed to keep out less threatening enemies — like hungry goats, for example. Traces of ancient agriculture to the west of the wall suggest that the structure may have served as a boundary between ancient farmlands and the pastures of nomadic farmers, according to archaeologists with the Aerial Archaeology in Jordan project. [See Photos of the Mysterious Ancient Wall in Jordan]

The Big Circles

The Khatt Shebib isn't the only ancient structure in Jordan that has archaeologists puzzled; Stone circles, dating back 2,000 years and dotting the Jordanian countryside, also have scientists scratching their heads.

Known simply as the "Big Circles," 11 of these structures have been spotted so far in Jordan. The circles are about 1,312 feet (400 m) in diameter and are just a few feet high. None of these short-walled circles have openings for people or animals to walk through, so it's unlikely that they are ancient examples of livestock corrals, according to archaeologists. So what exactly were they for? No one knows.

Researchers are now comparing the Big Circles with other circular stone structures in the Middle East to figure out their mysterious purpose.

The Cochno Stone

What is it with all these mysterious stones? In 2016, archaeologists in Glasgow, Scotland, excavated a 5,000-year-old stone slab (and its enigmatic history).

The so-called Cochno Stone measures 43 feet by 26 feet (13 by 8 meters) and contains swirling patterns known as "cup and ring marks" that have also been identified at prehistoric sites in other parts of the world. The slab may be an example of ancient artwork, according to Kenny Brophy, an archaeologist and senior lecturer at the University of Glasgow.

Researchers who studied the Concho Stone in the 1930s believed the stone's inscriptions may have been linked to astronomical phenomena, like eclipses, but Brophy doesn't think that's the case. He and his team of researchers are currently studying the stone more closely to discern how prehistoric people may have used it.

Super-Henge

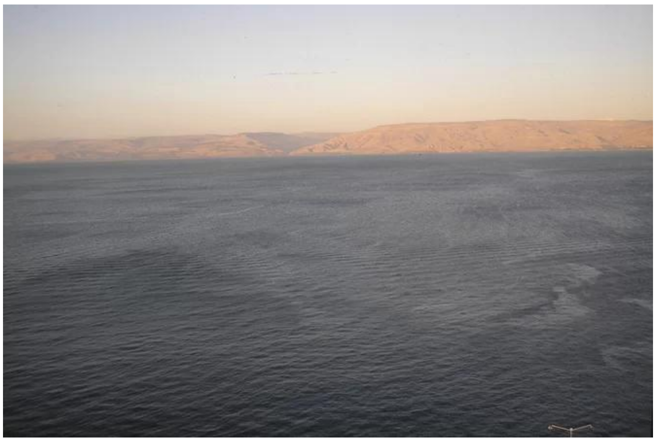
And now for the mother load of mysterious stones: Meet Super-Henge, a massive stone monument located just 2 miles(3.2 km) from Stonehenge in the U.K.

The huge monument, which is made up of a collection of stone monoliths, was unearthed in 2015. Archaeologists found the monoliths beneath the bank of the Durrington Walls (a grass-covered, circular embankment). This super-henge was probably part of a huge Neolithic monument of some sort, according to researchers.

Archaeologists aren't sure of the stones' original purpose, but they believe that the 15-foot-tall (4.5 m) slabs once stood upright before they were pushed over some 4,500 years ago. The giant monument stands at the site of a natural depression near the Avon river, and it's possible that the stones once helped form a C-shaped "arena" where springs and a valley led down to the river.

Underwater cairn

In 2003, scientists in Israel discovered an enormous stone structure beneath the Sea of Galilee. The monument, which is made up of many giant stones placed on top of one another, weighs an estimated 60,000 tons (heavier than most warships) and rises nearly 32 feet (10 meters) high.



The scientists who found this underwater rock pile, or cairn, have no idea what it may have been used for, though cairns in other parts of the world traditionally mark burials, according to the researchers. Other huge rock structures are located nearby, though none of these known structures are underwater. It's possible that rising sea levels submerged what was once a land-based cairn, the researchers explained after the discovery. Yitzhak Paz, of the Israel Antiquities Authority and Ben-Gurion University, believes this aquatic monument could date back more than 4,000 years. It may be the remains of some kind of fortified settlement, Paz told Live Science in 2013. [See Photos of the Mysterious Sea of Galilee Structure]

Holey jar

Archaeologists have unearthed plenty of holy artifacts, including jars, but uncovering a holey jar (i.e. a jar full of holes) was a first for researchers. The jar, which was initially recovered from a bomb crater outside of London after WWII, dates back to Roman Britain (the part of Britain under Roman rule from about A.D. 43 to 410), and researchers speculate that it may have been used as a lamp or as a kind of animal cage for either mice or snakes. However, these possible uses are really just educated guesses, according to archaeologists.

The strange-looking vessel is on display at the Museum of Ontario Archaeology in Canada, where researchers are waiting for someone to come along who has seen a similarly holey jar and who might know the purpose of such an item.

(Heather Whipps and Elizabeth Peterson, October 27, 2016, https://www.livescience.com/29594-earths-most-mysterious-archeological-discoveries-.html?utm_source=ls-newsletter&utm_medium=email&utm_campaign=20170825-ls)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

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Κυκλοφόρησε το Τεύχος # 3 του Τόμου 11 του ISSMGE Bulletin (Ιουνίου 2017) με τα ακόλουθα περιεχόμενα:

- Message from the President and the Chair of the Innovation and Development Committee (IDC)
- Research highlights – Geotechnical Group at Nanyang Technological University, Singapore
- Conference reports
  - The 18th Brazilian Congress on Soil Mechanics and Geotechnical Engineering
  - The 3rd International Conference on Transportation Geotechnics 2016 (Portugal)
  - The 14th International Conference on New Challenges in Geotechnical Engineering (Pakistan)
  - Transportation Geotechnics and Geoecology (TGG-2017) (Russia)
  - Half-day seminar: Centrifuge modelling in research and practice (Thailand)
- 7 ISSMGE Foundation reports
- Obituary – Professor Ken Been
- Event Diary
- Corporate Associates
- Foundation Donors- Corporate Associates

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Κυκλοφόρησε το Τεύχος #145 του **Newsletter του Geoengineer.org** (Ιουνίου 2017) με πολλές χρήσιμες πληροφορίες για όλα τα θέματα της γεωμηχανικής. Υπενθυμίζεται ότι το Newsletter εκδίδεται από τον συνάδελφο και μέλος της ΕΕΕΕΓΜ Δημήτρη Ζέκκο (secretariat@geoengineer.org).

Ενδεικτικά αναφέρονται:

- Innovative piled raft foundation scheme used on building project in London
- Scientists in search for hints about Caribbean earthquakes
- Massive landslide buries part of California highway (video)
- Landslide in Kyrgyzstan kills 24 (video)
- Landslide Prediction System successfully tried in Thailand
- New early warning system could have saved lives during the 2011 Japan tsunami
- Deadly M5.5 earthquake hits Xinjiang, China

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ΕΚΤΕΛΕΣΤΙΚΗ ΕΠΙΤΡΟΠΗ ΕΕΕΕΓΜ (2015 – 2018)

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