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Research paper

Geotechnical sustainability in the United Arab Emirates - Current status and opportunities

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Abstract

The United Arab Emirates (UAE) has aligned its development polices and agendas with the United Nation's Sustainable Development Goals, a driver provided by the UN to contribute towards sustainability. As part of this commitment, sustainability in the construction industry is continually evolving. The movement towards sustainability in construction is challenging in the UAE due to the climate, geographical location, economy and availability of natural resources. The UAE has therefore developed specific legislation requiring "green construction". Over and above the legislation, developers in the UAE recognise the value in achieving certified "green" credentials through the adoption of optional sustainability assessments in their projects. Geotechnical engineering is a specific branch of civil engineering focussing on soil-structure interaction and geotechnical input is required for the design and construction of almost every civil engineering project. This study reviews the current mandatory regulations and practices, with respect to the input from geotechnical engineering. It highlights that as a discipline there is little contribution towards sustainability and concludes that geotechnical engineering can and needs to contribute more. Practical solutions to improve geotechnical engineering sustainability are proposed, as are opportunities for further research and development of geotechnical engineering sustainability.

Keywords: *Engineering Sustainability; Geotechnical Engineering; Legislation; United Arab Emirates.*

1. The United Arab Emirates

The United Arab Emirates (UAE) is a constitutional federation of seven Emirates; Abu Dhabi, Dubai, Sharjah, Umm al-Quwain, Ajman, Ras al Khaimah and Fujairah. The two largest cities in the Emirates are the capital Abu Dhabi and Dubai with populations of around 1 million and 3 million respectively. The UAE is located in the North East of the Arabian Peninsula, sharing land borders with the Kingdom of Saudi Arabia and Oman and a maritime border with Iran (Fig. **1**). With a population of almost 10 million, a diverse economy and two of the most prominent cities in the Middle East (Abu Dhabi and Dubai), the UAE is a regional and global economic centre.

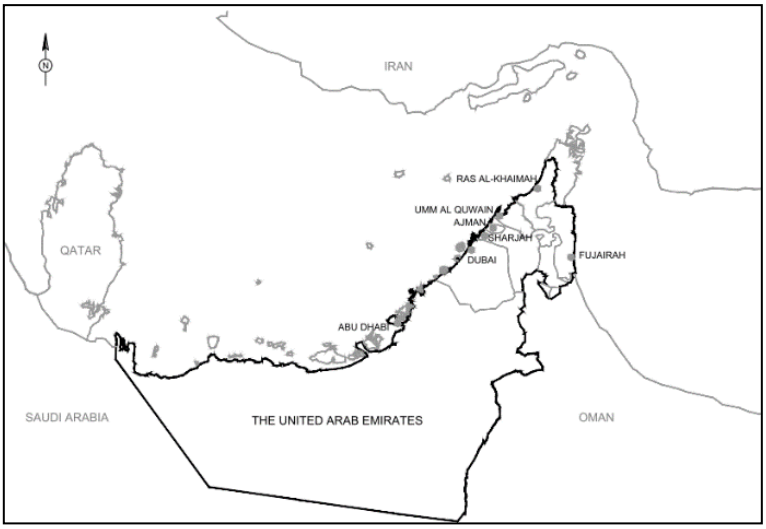


Fig. 1: The United Arab Emirates and Its Principal Cities.

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The construction sector contributes 10% of the Gross Domestic Product (GDP) of the UAE (United Arab Emirates Ministry of Economy, 2017). Investment in construction forms a consistent part of government spending with billions of dollars ear-marked for projects such as Etihad Railway and Dubai's World Expo 2020.
The UAE has over 200 buildings taller than 150m (considered to be minimum height to be defined as a skyscraper) and Dubai ranks as third in the world by number of constructed buildings which are 150m high or taller (Council on Tall Buildings and Urban Habitat).
The UAE has a desert climate, with high temperatures in the summer (average maximum temperature is 45.0 degrees Celsius) and relatively high temperatures in the winter (the minimum average temperature is 13.0 degrees Celsius) (Statistic Centre Abu Dhabi). Typical average monthly rainfall varies from 0mm in the summer months to 13mm in the winter months (Statistic Centre Abu Dhabi).
The combination of high temperatures and low rainfall, in conjunction with wind speed and blowing force, results in scarcity of natural water resources. Water resource management is critical in the UAE and the Middle East in general (Jowitt, 2004). Water supplies and access to equitable water forms part of national strategy, such as the UAE Water Security Strategy 2036 (United Arab Emirates Water Security Strategy).
The World Wildlife Fund (WWF) issues the Living Planet Report "to show the state of the natural world". In the 2006 report (World Wildlife Fund, 2006), the United Arab Emirates had the largest ecological footprint per person, per country, in the world, predominantly because of its carbon emissions. In 2010 (World Wildlife Fund, 2010), the United Arab Emirates had reduced it per capita ecological footprint but was still the third highest in the world (behind its Middle Eastern neighbours, Kuwait and Qatar). In 2016 the report highlighted that the United Arab Emirates is still amongst the countries with the highest footprint (World Wildlife Fund, 2016).

2. Sustainability

Sustainability is defined as "the ability to be maintained at a certain rate or level" (Oxford Dictionaries). Its use has become widespread, in all walks of life, as the understanding grows that the Earth's resources are finite whilst, at the same time, the desire for better property and possessions is growing. Earth's resources are being consumed at an ever-increasing rate without the ability to increase the Earth's resources and the effect on the planet is well documented (e.g. in the Living Planet Reports (WWF, 2016)). Iai (2011) proposed that "global sustainability is the greatest long-term challenge of our time" and recent reports from WWF suggest that this may be the case.
The demand for environmentally friendly and sustainable alternatives is rising. This is evident in all sectors and civil engineering is no different.

3. Sustainable development

Sustainable development as a concept grew from the ever increasing realisation that population growth, industrialisation and resource depletion were having short-term impacts and long-term implications on the environment. It is now understood that these implications are a reduction in the quality of life, through increased pollution, lack of natural resources and loss of biodiversity.
The United Nations (UN) brought sustainable development into the public sphere in 1987 with the publication of the Brundtland Report (Brundtland, 1987). The report defines sustainable development "as development that meets the needs of the present without compromising the ability of future generations to meet their own needs". As the world has changed since 1987, so have the objectives of the UN. In 2000, eight Millennium Development Goals (MDG) were agreed by the UN Member States. One of the goals was to ensure environmental sustainability. The current 2030 Agenda (United Nations, 2015) has identified 17 Sustainable Development Goals (SDG). The SDG are an update of the MDG and have identified new priorities such as climate change, innovation and sustainable consumption.

4. Engineering sustainability

Civil engineering is the process of designing, constructing, managing and operating projects such as airports, roads, buildings and tunnels. The Institute of Civil Engineers (ICE) classifies civil engineering as "everything you see that's been built around us". Consequently, it is easy to understand that all civil engineering projects have an environmental, social and economic impact (the traditional three components of sustainability).
Civil engineering sustainability is the process of taking into consideration the impact of civil engineering projects in the design, construction, management and operating phases. Civil engineering sustainability is therefore fundamental to achieving the UN Sustainable Development Goals (SDGs) (United Nations, 2015).
The key SDGs, with respect to civil engineering, are:

- Goal 6: ensure availability and sustainable management of water and sanitation for all
- Goal 7: ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8: promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9: build resilient infrastructure, promote sustainable industrialisation and foster innovation
- Goal 11: make cities inclusive, safe, resilient and sustainable
- Goal 12: responsible production and consumption
- Goal 13: take urgent action to combat climate change and its impacts

In much the same way that Iai (2011) identifies global sustainability as the biggest challenge of our lifetime, Pantelidou et al., (2012) identify that sustainability is the biggest challenge facing engineering in our lifetime.

5. Sustainability assessments

Internationally, civil engineering has adopted various drivers and methods to improve the performance of sustainability for projects. Typical drivers and methods are local legislation, project requirements or by applying sustainability assessment, rating and award schemes (hereafter referred to as "sustainability assessments").
Sustainability assessments is the process of evaluating how sustainable a project is. Most sustainability assessments are applied by an independent third party which acts as an assessor. The assessor applies the chosen sustainability assessment framework to evaluate the projects sustainability performance whilst identifying areas of improvement. Frameworks covers a range of categories depending on the

type and scope of the project, location and the specific requirements of the chosen sustainability assessment. Example categories include water, energy and materials. Once the sustainability assessment is completed a score that reflects the project sustainability performance is awarded. By awarding a performance rating it is hoped that each project will strive for the highest award and therefore the highest level of sustainability.
A companion paper (Sochanik, 2020) provides a detailed description of the various sustainability assessments in use in the UAE.

6. Civil engineering sustainability in the UAE

Shareef and Altan (2016) highlight the need for local sustainability practices so that the local conditions, regulatory requirements and construction practices are taken into consideration and building performance is increased. This is especially true in the UAE with an extreme climate and the construction of mega structures.
The Emirates of Dubai and Abu Dhabi have developed local sustainability programmes and assessments, focussing on the challenges and opportunities specific to the region. Ras al Khaimah is currently piloting sustainability regulations with the aim of being mandatory in 2020. Sustainability regulations require significant input from civil engineers.

6.1 Abu Dhabi – Estidama

The Estidama system is one of the foundation blocks of Abu Dhabi's Vision 2030, having recognised that "the UAE has almost the highest rate of energy consumption per person in the world (UPC, 2010)". Estidama, which is the Arabic word for sustainability, is an initiative to promote sustainable design and construction in the built environment. Implemented in 2008, it is an initiative that provides resources and procedures, as well as more traditional sustainability assessments, to promote sustainable development.
One initiative within Estidama is the Pearl Rating System. The Pearl Rating System is a sustainability assessment and was designed to ensure sustainability throughout the construction life cycle (from design through construction to operation) for buildings, communities and villas. It has been mandatory for all new buildings in the Emirate of Abu Dhabi since 2010.
The Pearl Rating System (PRS), as a sustainability assessment, can be used on three types of projects:

- Pearl Community Rating System: Planning
- Pearl Building Rating System: Design & Construction
- Pearl Villa Rating System: Design & Construction

After each assessment, a number of Pearls is awarded, based on the project's sustainability rating. One Pearl is the lowest rating and Five Pearls is the highest. Minimum Pearl ratings are required for different structures (for example, Mosques must achieve a minimum of Two Pearls).
Estidama is applied only to buildings, communities and villas. At present in the Emirate of Abu Dhabi there are no other mandatory local sustainability assessments, notably for sustainable infrastructure (rail, maritime or roads projects).

6.2 Dubai - Green Building Regulations and Specification

The Emirate of Dubai incorporated the Green Building Regulations and Specification (GBRS) in 2009. The aims of the regulations were to save energy and water and lower CO_2 emissions. The regulations are focused on:

- Envelope Efficiency
- Cooling System
- Water Use
- Indoor Environment Quality
- Energy Efficiency
- Site Heat Island.

It is recognised that the GBRS is not an assessment (i.e. no classification/award is given) but provides regulatory requirements to be followed to meet the green building standards.
Some examples of the minimum requirements include that building materials contain at least five percent (5%) recycled content and at least five percent (5%) of the total volume of materials used are to be regionally sourced (Dubai Municipality, 2011).

6.3 Dubai - Al Safat

Dubai has built on the initial foundations set by the GBRS and produced a sustainability assessment called Al Safat. New buildings in Dubai are required undertake the Al Safat assessment, those that don't meet the minimum standard will not receive a building permit. A minimum level of sustainability is therefore required for every new building in the Emirate of Dubai (Dubai Municipality, 2017).
The categories assessed by Al Safat:

- Ecology and Planning
- Building Vitality
- Resource Effectiveness: Energy
- Resource Effectiveness: Water
- Resource Effectiveness: Materials and Waste

The rating system classifications are platinum, gold, silver and bronze.
Currently, the mandatory sustainability requirements are only for villas and buildings. The requirements do not extend to the other facets of civil engineering such as roads, ports or rail.

6.4 Ras al Khaimah - Barjeel

Ras al Khaimah is the latest Emirate to adopt civil engineering sustainability through the RAK Energy Efficiency and Renewable Energy Strategy 2040. In 2019, the first green building regulations, Barjeel, were adopted to provide more sustainable buildings, communities and cities (Government of Ras al Khaimah, 2019).
The regulations are split into five categories:

- Energy efficiency
- Water efficiency
- Renewable energy
- Material & resources
- Comfort & well-being

The Barjeel initiative is not am assessment but a set of minimum regulations that must be met in design and construction.

6.5 The Other Emirates

In the remaining Emirates there are no specific sustainability practices. Any Emirate(s), Client or project may adopt best international practice but there is no mandatory requirement.

7. Geotechnical sustainability

7.1 What is Geotechnical Engineering

Krynine and Judd (1957) describe geotechnics as the application of earth sciences to the solution of civil engineering problems. Practically, it is the engineering of interactions with the ground (whether that is from a structure, groundwater or from other soils). It has developed into a specialist branch of civil engineering as the understanding of the impact of ground conditions has grown. Although initial geotechnical engineers were expected to only provide information on foundation materials, it now encompasses a wide range of applications:

- Ground investigation
- Ground characterisation
- Foundation design
- Temporary excavation solutions
- Grouting design
- Geotextiles
- Ground anchors design
- Retaining walls
- Tunnels
- Earthworks
- Slope stability
- Ground improvement

For the context of this paper geotechnical engineering is considered to include all the standalone aspects of geotechnical engineering defined above as well as foundation design (piles and shallow footings) which may form part of the structural design submissions (especially in the UAE).
Geotechnical engineering has also branched into specialist engineering disciplines:

- Instrumentation and monitoring
- Contaminated land remediation
- Dewatering
- Seepage analysis
- Geophysical surveys
- Energy geotechnics

Energy geotechnics (hydro-storage, geothermal piles, ground loop heat exchange, heat loss/gain of underground structures, carbon storage etc.) in particular requires specialist knowledge.

7.2 What makes Geotechnical Engineering a fundamental element of Civil Engineering

Geotechnical engineering is a vital component of civil engineering. Its importance is perhaps best illustrated by a quote from the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) “anything that is not supported by soil or rock either floats, flies, or falls down”. An in-depth understanding of ground behaviour is fundamental to design safe and optimal solutions for all geotechnical elements. The field of geotechnical engineering also accounts for the influence of groundwater conditions on design and construction. Lastly, geotechnical engineering is required as part of the design regulations to be carried out on civil engineering projects. These examples all illustrate the critical element that geotechnical engineering is of civil engineering.
It is estimated that site investigation costs are around 0.1% of the overall build cost, yet ground related problems typically account for about one-third to one-half of construction programme over-runs (Butcher et al., 2006). Ground works, including foundation construction, are often on the critical path for programming. Delays during this stage easily disrupt the construction programme.

7.3 Why embedding sustainable solutions with Geotechnical Engineering is critical

Soil in one form or another covers most of the surface of the planet yet geotechnical sustainability does not seem to be a big factor in global sustainability (Iai, 2011).
Geotechnical engineering needs to be involved in sustainability for the following broad reasons:

Geotechnical engineering is required on almost every project
Civil engineering projects, be that buildings, infrastructure or masterplanning, almost always require geotechnical input into design and construction. Although there are many applications where geotechnical engineering is a standalone discipline (for example in a slope instability and remediation project) the majority of projects require interaction with other disciplines. Typically, the management and design focus is not led by geotechnical engineers.

There is, therefore, a need for geotechnical engineering to contribute towards sustainable solutions in the wider project context (Basu et al., 2015).

Geotechnical engineering input is typically required at the start of the project where the scope to embed sustainability is at its largest
It is well documented that to have the most sustainable project, sustainability must be considered at the very beginning of the project (Pantelidou et al., 2012). Geotechnical engineers are, by virtue of being the first design element in a typical construction project, in a unique position to make a significant contribution to the sustainability of construction projects.

Geotechnical engineering encompasses a wide variety of applications
The wide range of geotechnical applications means that the approaches to design, construction, procurement and management on every project vary. The requirements for slope stability are very different from tunnel construction which is again different from permeation grouting for waterproofing projects. The range of applications described in Krynine and Judd (1957) is still valid and has only increased with innovations in design and construction in geotechnical engineering.

Ground works often involve a significant quantity of natural materials
Chang et al., (2016) estimate that geotechnical applications are responsible for approximately 2% of the total CO_2 emissions by cement (data from 2011). Chang et al., (2016) also highlight that cement related CO_2 emissions are rising.
In addition, geotechnical applications also require a wide variety of other resources including steel, petrol, imported soils and rocks, chemical compounds and plastic.

Geotechnical construction is currently not sustainable
Geotechnical construction, such as piles, foundations, retaining walls and tunnels, require a large quantity of non-renewable energy and material resources (cement, steel etc.). Furthermore, there is also generation of wastes and other environmentally damaging by-products, high usage of energy to create construction materials and emissions of harmful gases by machinery (Iai, 2011). This problem is exacerbated as it occurs during material production, transportation and construction
At present, geotechnical engineering practices are not sustainable (Basu et al., 2015). It is therefore apparent that current geotechnical practices must change to be more sustainable.

Geotechnical engineering sustainability and its importance has been stressed by several authors (e.g. Shillaber 2016; Fragaszy et al. 2011; Mitchell and Kelly 2013). Geotechnical engineers must embrace the sustainability challenge, if not take a leading role, as there is an opportunity to make a significant contribution to the environmental impact, energy consumption and resource depletion of civil engineering projects.

8. Sustainability strategy of the UAE

The UAE Government has made sustainable development a priority, identifying it as one of six pillars which form part of its National Agenda in line with Vision 2021 (United Arab Emirates, 2010). The goal of protecting the environment while maintaining social and economic development is monitored and the progress made by the UAE is analysed.
The UAE has initiatives to diversify the GDP and have launched the Green Economy initiative as part of the Vision 2021 plan. Under the initiative "the UAE seeks to become a global hub and a successful model of the new green economy, to enhance the country's competitiveness and sustainability and preserve its environment for future generations."
In addition to the National Agenda, the UAE has federal policies and initiatives which were implemented to encourage sustainability and achieve the Sustainable Development goals, as set out in the UN 2030 Agenda. Some examples include:

- Abu Dhabi Environment Vision 2030
- Dubai Clean Energy Strategy 2050
- Sustainable cities

As shown in the implementation hierarchy in Fig. **2**, worldwide policies such as the Kyoto Protocol have the greatest impact on sustainability. This is because countries, companies and people must follow these policies. National policies, either determined by worldwide policies or by any Government's own initiative, have the second greatest impact as they can influence federal policies and Client requirements. Although company and individual actions are important for sustainability, they have the least impact.

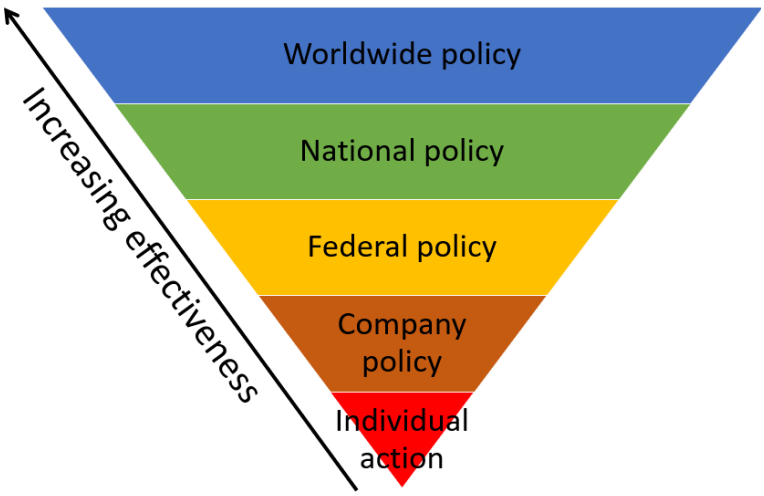


Fig. 2: Hierarchy for Successful Implementation of Sustainability.

9. Assessment of existing geotechnical sustainable practices in the UAE

In the United Arab Emirates, the legislative requirement to consider sustainability in a civil engineering project is limited to the mandatory regulations (e.g. Al-Safat), in certain Emirates (e.g. Dubai), and for certain engineering sectors (e.g. for building, villa and community projects). However, this is not the case in other countries (assessments are optionally used), so the UAE can be considered to be proactive in civil engineering sustainability. The number of civil engineering projects which are certified with a non-mandatory assessments in the UAE (e.g. LEED (USGBC, 2014)) is also relatively high (though the number of civil engineering projects in the UAE is also relatively high). It is evident that there is a desire to improve sustainability in civil engineering projects in the UAE from the Government and Clients.
In the wider civil engineering context there are a large number of projects which do not fall into the mandatory requirements for example, ports, bridges, roads, tunnels, oil and gas plants, airports etc.
Currently there are no sustainability initiatives focusing on geotechnical engineering in the UAE. As a result, for geotechnical engineering to make an impact it must be included within the mandatory assessment or, if the Client has requested for an optional assessment, international certification.
The Government as an informed Client does not currently assess the contractor / designer credentials when tendering work. Furthermore, there is little emphasis on sustainability in the design and construction of projects which are not included in the mandatory regulations for sustainable design.

10. Proposed practical solutions for geotechnical engineering sustainability

It is clear from the UAE policies (such as Vision 2021 (United Arab Emirates, 2010)) that there is both significant proposed investment in buildings and infrastructure and an appetite for sustainable development. There is a need for further efforts towards engineering sustainability and geotechnical engineering can contribute.
The fact that civil engineering sustainability is mandatory within the Estidama and Al Safat initiatives shows the UAE is proactive however:

- Sustainability needs to be promoted on all projects, not just those that fall into the current mandatory regulations
- Not all of the Emirates have sustainability regulations
- More initiatives could be developed to cover more types of projects

Increasing civil engineering sustainability will in turn open up further opportunities for geotechnical sustainability.
Geotechnical sustainability in the United Arab Emirates, as a discipline specific element, is not developed. Geotechnical sustainability is not a common consideration worldwide, so it is unsurprising that there are no initiatives in the United Arab Emirates. The opportunities for geotechnical engineering to contribute to a sustainable project, within the current regulations, are limited. As a consequence, there are opportunities to develop geotechnical sustainability:

- Promote geotechnical sustainability from project inception and to all stakeholders
- Consider earthworks management
- Develop geotechnical categories within the current assessments or develop specific geotechnical assessments

Fig. **3** presents the overall proposal to firstly improve civil engineering sustainability then improve geotechnical sustainability.

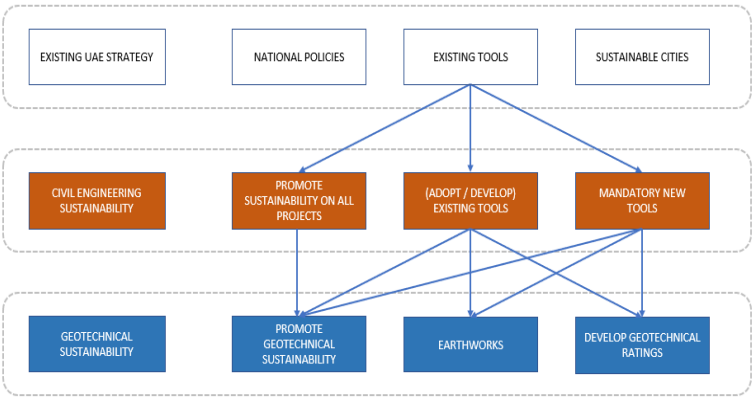


Fig. 3: Proposal to Increase Sustainability Across the UAE.

Promote sustainability on all civil engineering projects

The National Climate Change Plan of the United Arab Emirates (United Arab Emirates Ministry of Climate Change & Environment, 2017) recognises that "the future of the country is contingent on our ability to manage our national resources with wisdom and keenness on the interests of the future." Managing resources needs to be the aim across all projects. The first major change that could be made to deliver more sustainable projects is to promote sustainability on all civil engineering projects (small and large, single and multi-discipline, within and outside the current sustainability assessments).
In the United Arab Emirates Sustainability Strategy section, it is highlighted that setting national policies is one of the most effective ways of implementing civil engineering sustainability. The emphasis is therefore on the Government to demand sustainability from the tender stage, through design and construction and finally during operation.

Promote geotechnical sustainability

Geotechnical engineers need to take the lead in educating project managers, architects, sustainability consultants, Clients etc to have a better understanding of the work done by geotechnical engineers and our importance to sustainability. It is an engineer's responsibility to persuade the opinion formers that they interact with – especially our Clients – to adopt new approaches to their development projects.
Geotechnical engineers, like all stakeholders, have the greatest chance to improve sustainability if they are engaged early in the project. Inclusion of geotechnical engineers in the integrated development team needs to be mandatory.
Although foundations and substructures have the largest potential to improve sustainability, all elements of geotechnical engineering can contribute to sustainable projects:

- Reducing water consumption during construction
- Reducing materials used, especially in the construction phase
- Recycling of earthworks materials for fill and landscaping
- Reducing construction and demolition waste

Change the way projects are awarded and success evaluated

Every Client could implement small but significant changes to improve project sustainability:

- At the tender evaluation stage (during contract award for lead designer and contractor):
- Request examples of previous sustainable practices
- Add sustainability as a criterion when evaluating tenders and awarding contracts
- Request sustainability updates during the design and construction
- Set minimum sustainability requirements (which could match the assessment requirements)
- Promote and accept innovation
- Judge project success on the environmental outcome (in addition to time and cost)

If at the tender stage, the main criteria for a successful bid is the lowest price, then there is already an opportunity missed to embed sustainability into the project.
In a similar way, if Clients only consider success in terms of meeting the programme and budget, then the opportunity to explore sustainable options and maximise the potential for sustainability is diminished.

Work in conjunction with Contractors

Contractors and consultants (including geotechnical engineers) need to be working together to evaluate alternative solutions and to develop the practical use of new and non-traditional materials (e.g. recycled materials, typically unsuitable materials etc). By working together, a design that works in construction can be achieved. It is up to both Geotechnical Engineers and Contractors to push the design boundaries.

Sustainability assessments

Sustainability assessments are adopted internationally to improve the sustainability performance in engineering projects and the UAE have followed suit. Nonetheless, there are many opportunities to develop the assessments to increase the contribution from sustainable solutions embedded in geotechnical engineering to help improve the sustainability performance of projects.
A companion paper (Sochanik, 2020) provides a detailed assessment of how sustainability assessments in the UAE could be adopted, improved or developed. The opportunities are broadly categorised as:

- Make assessments mandatory in all Emirates (for example, Sharjah)
- Adopt assessments for all projects (for example, ports and tunnels)
- Further develop local assessments
- Encourage inclusion of geotechnical sustainability within the current assessments
- Adopt standalone geotechnical assessments (for example, in geotechnical engineering this could include embankments and cuttings, especially with retention systems)

11. Areas for further research and development

The author has focused on a specific part of sustainability in the UAE, namely the current legislative requirements, to assess the contribution of geotechnical engineering to sustainability.
Within any project there is the chance to exceed the minimum sustainability targets, if the will and desire is there. In any typical design cycle there are four stakeholders, each with a specific, important and necessary role to play to increase sustainability in projects:

- The Client (including the Client's engineer)
- The Engineer (including the lead designer, independent checker, etc.)
- The Contractor (including all sub-contractors)
- The Approval Authority

The current status of each of the project stakeholder's contribution to sustainability needs to be assessed. This would allow the constraints to be understood and potential opportunities to be explored.
Within the UAE, the adoption and development of sustainability assessments offer a significant opportunity to enhance the sustainability of projects. This is true of both engineering in general and geotechnical engineering. If the UAE is to continue promoting sustainability as a national agenda then they need to lead the field in ensuring all projects are working towards sustainability. Internationally there is a need to review the assessments to further include geotechnical engineering. There is also opportunity for an academic review into standalone geotechnical assessments.
There are many definitions of sustainability and it is recognised that there are many more aspects that can be considered. For example, there is potential to develop techniques to deal with resilience and adaptability – consideration of future scenarios so that sustainability is considered in the long term, even if the immediate design choice is not the most sustainable option in the short term.

Finally, there is significant research into sustainable materials and procedures in academia. Methods to expedite these sustainable methods into civil engineering projects need to be addressed. Civil engineers are notoriously slow at adopting change and moving away from the "industry practice" status quo.
There are a wide range of opportunities for further research as it is recognised that there is no single right answer to achieving sustainability (Jowitt, 2004). Each single action taken towards achieving the goal will be beneficial.

12. Conclusion

The United Arab Emirates has successfully incorporated sustainability into legislation and national policy, including in the construction industry. That said, geotechnical sustainability has not made the same progress as it is often been overlooked within civil engineering sustainability.
Geotechnical engineering is required on almost every project, it encompasses a wide variety of applications and involves a significant quantity of natural materials. Geotechnical engineering must, therefore, form part of every construction project's sustainability execution plan. Furthermore, geotechnical engineers must take the lead in developing their own capabilities, driving sustainability measures and informing Clients.
Practical solutions to improve geotechnical sustainable practices in the UAE have been presented; from adaption of the current legislation and policies through project award and promoting geotechnical sustainability on all projects.
In addition to the practical solutions proposed, areas for further research have been identified, all of which can help towards fully integrating geotechnical sustainability in the UAE (and further afield).

References

[1] Basu D., Misra A. and Puppala, A.J (2015), Sustainability and geotechnical engineering - perspectives and review, Canadian Geotechnical Journal, 52: 96–113. https://doi.org/10.1139/cgj-2013-0120.
[2] Brundtland, G.H. (1987), Our common future: report of the World Commission on environment and development. Oxford University Press, UK.
[3] Butcher A. P., Powell J. J. M. and Skinner H. D. (2006), Reuse of foundations for urban sites - A best practice handbook, IHS BRE Press, Bracknell.
[4] Chang. I, Im. J and Cho. G (2016), Introduction of Microbial Biopolymers in Soil Treatment for Future Environmentally Friendly and Sustainable Geotechnical Engineering, Sustainability 2016, 8, 251. https://doi.org/10.3390/su8030251.
[5] Gaba A, Hardy S, Doughty L, Powrie W and Selematas D (2017) Guidance on Embedded Retaining Wall Design. Construction Industry Research and Information Association, London, UK, C760.
[6] Council on Tall Buildings and Urban Habitat, Skyscraper data centre https://www.skyscrapercenter.com/country/united-arab-emirates.
[7] Dubai Municipality (2011), Green Building Regulations and Specifications. Dubai Municipality, Dubai, UAE greenbuilding@dm.gov.ae.
[8] Dubai Municipality (2017), Al-Safat. Dubai Municipality, Dubai, UAE.
[9] Fragaszy, R. J., et al. (2011), Sustainable development and energy geotechnology - Potential roles for geotechnical engineering, KSCE Journal Civil Engineering, 15(4), 611 – 621. https://doi.org/10.1007/s12205-011-0102-7.
[10] Government of Ras al Khaimah (2019), Barjeel Green Building Regulations and Specifications. RAK, UAE.
[11] Iai, S. (2011), Geotechnics and Earthquake Geotechnics Towards Global Sustainability, Springer Dordrecht Heidelberg London New York. https://doi.org/10.1007/978-94-007-0470-1.
[12] Institute of Civil Engineers, https://www.ice.org.uk/what-is-civil-engineering.
[13] International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), https://www.issmge.org/.
[14] Jowitt, P (2004), Sustainability and the formation of the civil engineer, Proceedings of the Institution of Civil Engineers: Engineering Sustainability, Pages 79-88 Volume 157, Issue 2. https://doi.org/10.1680/ensu.2004.157.2.79.
[15] Krynine, D.P. and Judd, W.R. (1957), Principals of Engineering Geology and Geotechnics. McGraw-Hill Book Company, Inc., New York, 1-707.
[16] Mitchell, J. K., and Kelly, R. (2013) Addressing some current challenges in ground improvement. Proc. Inst. Civ. Eng. Ground Improv., 166(3), 127 – 137. https://doi.org/10.1680/grim.12.00030.
[17] Oxford English Dictionaries, https://www.lexico.com/en.
[18] Pantelidou H, Nicholson D and Gaba A (2012) Sustainable geotechnics. In Manual of Geotechnical Engineering (Burland J, Chapman T, Skinner H and Brown M (eds)). ICE Publishing, London, UK, vol. 1, pp. 125 – 135.
[19] Shillaber (2016), Energy and Carbon Assessment I, Journal Geotechnical and Geoenvironmental Engineering, 2016, 142(3). https://doi.org/10.1061/(ASCE)GT.1943-5606.0001410.
[20] Shareef and Altan (2016), Building sustainability rating systems in the Middle East, Proceedings of the Institution of Civil Engineers: Engineering Sustainability. https://doi.org/10.1680/jensu.16.00035.
[21] Sochanik, R. (2020), Geotechnical Sustainability in the United Arab Emirates–Sustainability Rating Tools, International Journal of Engineering and Technology (IJET), Vol.9, Iss.4, Pages 07-24, September 2020.
[22] Statistic Centre Abu Dhabi, https://www.scad.gov.abudhabi/en/pages/default.aspx.
[23] United Arab Emirates (2010), Vision 2021, https://www.vision2021.ae/en.
[24] United Arab Emirates (2015), Dubai Clean Energy Strategy 2050, https://government.ae/en/about-the-uae/strategies-initiatives-and-awards/local-governments-strategies-and-plans/dubai-clean-energy-strategy.
[25] United Arab Emirates Ministry of Climate Change & Environment (2017), National Climate Change Plan of the United Arab Emirates, www.moccae.gov.ae.
[26] United Arab Emirates Ministry of Economy (2017), Annual Economic Report 2017, 25th Edition.
[27] United Arab Emirates Water Security Strategy 2036, https://government.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/the-uae-water-security-strategy-2036.
[28] United Nations (2015), Transforming our World: The 2030 Agenda for Sustainable Development.
[29] UPC (2010), Pearl Building Rating System: Design & Construction, Version 1.0, Estidama, Abu Dhabi Urban Planning Council.
[30] USGBC (2016) LEED v4 for Building Design and Construction –Current Version. USGBC, Washington, DC, USA.
[31] WWF (2006), Living Planet Report 2006.
[32] WWF (2014), Living Planet Report 2014, Species and spaces, people, and places.
[33] WWF (2016), Living Planet Report 2016, Risk, and resilience in a new era.