Developing a New European Standard for Sustainable Earthworks

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Abstract

Earthworks, like most other human activities, need to become much more sustainable. This includes minimising carbon emissions and other environmental impacts from earthworks construction; restoration of biodiversity through use of regenerative and nature-based solutions; maintaining water quality and minimising its use; preservation and carbon sequestration of topsoils; minimising use of natural resources and greater use of circular economy; and developing resilient earth-structures.

Alan and Niall are the UK's technical experts on the CEN (European Committee for Standardisation) working group developing an important new document - the first European standard on Sustainable Earthworks. The first step in the process is to prepare a CEN "Technical Report". This will be framed around the United Nations Sustainable Development Goals and will also refer to the key policy areas of the European Green Deal. It will summarise the state-of-the-art for sustainable earthworks, some innovations which are currently being developed; and will sign-post key references. This paper discusses some of the main themes in the development of this new document.

Keywords: Earthworks, Sustainability, Resilience

1.Introduction

1.1 Origins of sustainable earthworks standard

There is an international climate emergency. Greenhouse gases have huge impacts on climate change. Human production of carbon dioxide and methane, etc., both considered as greenhouse gases, dramatically increases the temperature of the atmosphere. The most significant of them is carbon dioxide (CO_2), hence greenhouse gases are expressed in an equivalent of CO_2 weight (or "carbon" for short). We need to radically reduce carbon emissions over the next decade so as to reach net zero carbon by 2050 and so to keep global warming below 1.5 degrees above pre-industrial levels. Our critical infrastructure needs to be resilient as the impacts of climate change intensify. We also need to halt the catastrophic loss of biodiversity, a crisis almost as critical as climate change. That will all require transformational change including changes to policy and legislation, financing and expectations.

Earthworks is the most common aspect of civil engineering operations and earthworks materials are also by far the most widely traded commodity in Europe by volume. Like most other human activities, earthworks needs to become much more sustainable. The need for earthworks to be designed with sustainability in mind was highlighted in BS 6031, the British Standard Code of practice for earthworks in 2009 (BSI, 2009). Part 1 of the European Standard on earthworks, BS EN 16907 (BSI, 2018), further emphasised the importance of sustainable development and environmental considerations in the design and construction of earthworks.

In 2021, CEN (the European Committee for Standardisation) set up a working group to develop the first European standard on Sustainable Earthworks. The authors of this paper are the UK's technical experts on this working group. The first step in the process is to prepare a CEN "Technical Report".

"Sustainable earthworks" means the design and construction of earthworks to benefit both this generation and future generations, including responsible consumption of the planet's resources. It includes the planning, design, construction and maintenance stages of projects. The new standard will include the principal topics listed below. Some of them (but not all, due to space constraints) are discussed further in this paper:

- sustainable earthworks resource management to minimise waste;
- minimising emissions of greenhouse gases from earthworks construction;
- preservation of biodiversity through use of regenerative and nature-based solutions;

- preservation and carbon sequestration of growing soils;
- maintaining water quality and minimising its use;
- good environmental construction practices;
- developing earth structures which are resilient to the impacts of climate change; and
- minimising use of natural resources and greater use of circular economy in earthworks construction.

1.2 United Nations Sustainable Development Goals

Within the next decade, the 17 UN Sustainable Development Goals (SDGs) are expected to become the focus for much business and construction activity globally. The SDGs are summarised in Figure 1. The new sustainable earthworks standard will be framed around these SDGs. It will also refer to the key policy areas of the European Green Deal, a package of policy initiatives which aims to set the European Union (EU) on a path to a green transition and ultimately carbon neutrality by 2050 (EU, 2021).

The SDGs which are most intrinsically linked to earthworks projects are clean water; renewable energy; resilient infrastructure; sustainable cities and communities; responsible consumption and production; climate action; and preservation of biodiversity (SDGs 6, 7, 9, 11, 12, 13 and 15 respectively). The working group preparing the new standard decided that it should concentrate on the engineering and environmental aspects of sustainable earthworks and should not address issues associated with social value and social justice (SDGs 1, 2, 3, 4, 5, 10, 16 and 17 respectively).

Figure 1: The United Nations Sustainable Development Goals.

2. Sustainable earthworks resource management on infrastructure projects

2.1 Carbon management and PAS 2080

In 2016, a Publicly Available Specification (PAS) 2080 was published. This specifically addresses the management of carbon in infrastructure. An updated version is due to be published in 2023. PAS 2080 looks at the whole life cycle of the carbon used on projects and promotes reduced carbon, reduced cost infrastructure delivery and a culture of challenge in the infrastructure value chain where innovation can be fostered. The scope for reducing whole life cycle carbon emissions is greater during the initial project stages than in the later project stages, but the degree of knowledge required to deliver the project increases over time (BSI, 2016), as shown in Figure 2.

2.2 Developing a sustainable earthworks strategy at an early stage in a project

Geotechnical specialists are well placed to influence the design of a project at its earliest stages, as they are involved in early tasks such as the identification of ground risks during the desk study and ground investigation. This provides the potential to incorporate sustainable and resilient solutions into projects at the earliest stages;

and it can allow geotechnical specialists to challenge the scope and guide early decisions on how to achieve the optimum sustainable earthworks strategy for the project.

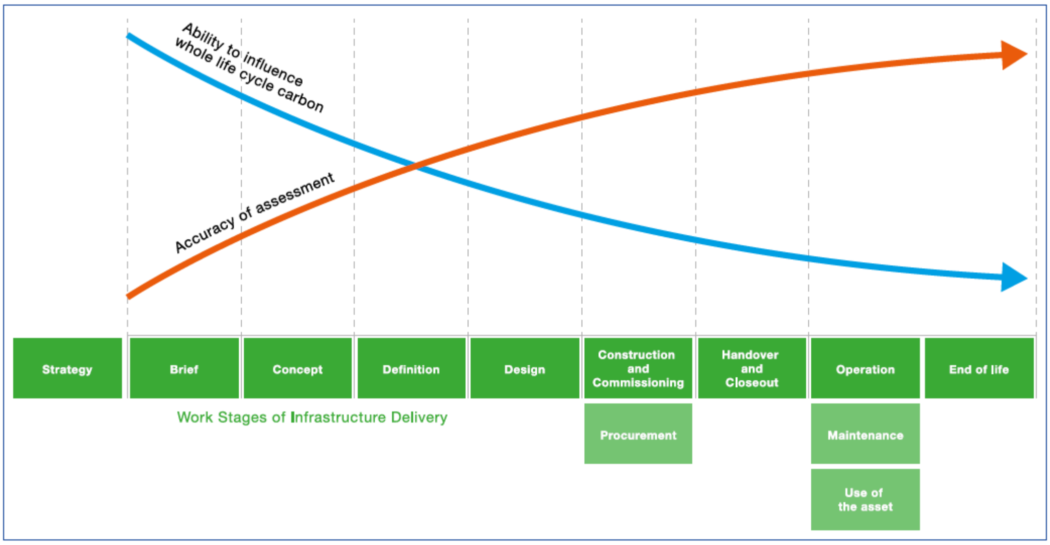

Figure 2: Conceptual diagram showing ability to influence carbon reduction across the different work stages of infrastructure delivery (from PAS 2080: 2016).

The volume of material to be excavated on a project should be minimised at all stages as this, self-evidently, minimises carbon and waste. The earthworks strategy should be recorded in a Preliminary Earthworks Strategy Report. This should be regularly updated as the design of the project develops. Such a strategy has the potential to embed some of the largest sustainability opportunities for the project which could include options to:

- reduce overall volume of cut and fill and aim to achieve a nett balance;
- maximise the on-site re-use of materials excavated on the site;
- minimise waste;
- minimise mass-haul (earthmoving) distances, reducing construction carbon emissions;
- increase the resilience of the earthworks design;
- limit disturbance of topsoil; and
- adopt landscape and other regenerative environmental earthworks for nett increase in biodiversity.

3. Importance of an integrated earthworks design approach

A good way to achieve many of the aims set out in the project earthworks strategy (described above) at planning and design stage is to adopt an “integrated earthworks design” approach whereby the necessary environmental mitigation earthworks are designed concurrently and collaboratively with the engineering earthworks and construction logistics requirements. Achieving as close as practicable to an earthworks balance is the key to this, just as it has been historically for earthworks in the past (Highways Agency, 1995). Wherever practicable this provides the environmental mitigation requirements using excavated material. Examples of this include using excavated materials to blend infrastructure projects into the local landscape terrain; for sound and visual screening; improvement of agricultural land; and creating the potential for ecological gain through earthworks designed for habitat creation. This is an iterative process as the design develops and requires a collaborative multi-disciplinary design team all working closely together. That team would typically include specialists in earthworks, civil engineering, ground engineering, construction logistics, landscape architecture, waste and resources, ecology, agriculture, noise, planning, costing and carbon.

The land take required for environmental mitigation earthworks needs to be carefully justified; and the impact on the carbon that is released through changes in land use and disturbance of topsoil also needs to be factored in. Also, in accordance with the Development Industry Code of Practice (CL:AIRE,2011) the volume of material to be used for environmental mitigation purposes should only be the quantity necessary to offset the adverse environmental effects of the proposed project.

One example was the first stage of the High Speed One project in Kent, South-East England (Armour, 2003). There, 8 million m^3 of fill, which was just over half of the total volume of material excavated from the 74 km section of the route in Kent, was placed and shaped to blend the railway into the landscape. This also had major biodiversity advantages, as described in Section 4 below. A similar approach is being used on High Speed Two as well as on many major highway schemes. An example of this is given by Hooton et al (2020) where a collaborative integrated earthworks design approach avoided the need for offsite disposal of 1.4 million m^3 material excavated from tunnels. That material was instead used to replace an open cutting with a cut and cover tunnel and the countryside was reinstated over that.

3. Minimisation of greenhouse gas emissions from earthworks construction

3.1 Diesel-powered plant in present-day earthworks construction

Modern earthworks construction is a highly mechanised activity, although it is still a relatively low-carbon activity due to the predominance of excavated natural materials. Most of the carbon footprint of earthworks results from the fuel used to power earthworks construction plant and from vehicles used to haul materials to and from sites. Earthworks is therefore fundamentally different from most construction activities (Hughes et al, 2011). This is a big opportunity to reduce the carbon footprint of earthworks.

3.2 Alternative fuels

Earthworks construction is highly mechanised and that equipment is powered almost exclusively by diesel fuel. In nearly all cases, the earthworks equipment has been, and continues to be, operated by people from workstations on the equipment itself. The movement of soils and rocks requires powerful and heavy equipment. The trend is for larger equipment to dilute the increasing cost of labour (operating the equipment) and to attract other economies of scale.

The emissions from the consumption of the diesel fuel are the single greatest atmospheric impact of earthworks construction and use of diesel fuel also depletes the Earth's finite resources. Therefore if the reliance on diesel fuel can be minimised then the environmental performance of earthworks will be considerably improved. European standards for emissions from construction equipment are enacted through a series of increasingly onerous "tiers". The UK is currently at European Tier 5. Major infrastructure clients stipulate the latest European emissions standards and this is an important way to reduce construction emissions.

Alternative, more sustainable, power sources and fuel types are being developed and principally comprise electricity (from batteries), hydrogen and hydrogenated fuel oils (vegetable oil). The trend for larger equipment has limited the adoption of some alternative power sources, particularly electricity, as the alternative power sources are currently more suited to smaller equipment, illustrated by their greater adoption in cars and light vehicles.

3.3 Automation of construction plant

There is a strong link between automation and environmental sustainability because automation removes the need for people to operate each item of equipment and therefore has the potential to reverse the trend for ever-larger equipment. As smaller equipment is more suited to alternative power sources, automation should aid the adoption of alternative power sources The earthworks practitioner should therefore plan earthworks to enable automation. The TRL publication PPR 994 (Guy et al, 2021) is a new UK code of practice for off-highway automated vehicles. It includes a case study of a successful trial of an autonomous articulated dump truck on Highways England's A14 Cambridge to Huntingdon Improvements scheme in 2018 – see Figure 3 (on next page).

3.3 Treatment of earthworks with quicklime

Hughes et al (2011) found that generally as costs fall so does the carbon produced. An exception was if hydraulic binders (e.g. lime) were added. The study showed that lime treatment was the correct approach from a cost and programme perspective, but because of the high embodied carbon content, it would not give the lowest carbon footprint. Other environmental factors are also important such as not using up scarce landfill capacity and not using primary aggregates except where essential.

Over the last decade since the paper by Hughes et al was published, binders with lower embodied carbon such as ggbs and lower carbon cements have been developed. The EU proposal to introduce a carbon levy in the next few years should encourage such decarbonisation initiatives. In the near future, technology for production of nearly-zero-carbon limes and cements will become available as hydrogen will be used to fuel the production plants and unavoidable carbon process emissions will be captured in them. The introduction of these innovative binders and a carbon levy are likely to transform the choices of earthwork solutions (including lime treatment) and their competitiveness.

Figure 3: Trial of autonomous articulated dump truck on Highways England's A14 Cambridge to Huntingdon Improvements scheme in 2018 (Photo copyright of Highways England and Blackwell Earthmoving Ltd).

4. Earthworks applications for preservation of biodiversity

The catastrophic loss of biodiversity is a crisis almost as critical as climate change. Earthworks, if planned, designed and constructed appropriately, can assist in achieving biodiversity net gain on infrastructure projects. This approach has been used on large infrastructure projects in the UK and elsewhere for at least 20 years.

As described in Section 3 above, on the High Speed One project in Kent, a large amount of landscape mitigation earthworks was placed and shaped to blend the railway into the landscape. Those landscape earthworks were then planted with 1.2 million trees and shrubs, or with grass and wildflower seed. The combined landscape treatment of earthworks and planting had major biodiversity advantages.

Another imaginative use of earthworks to improve biodiversity was on the Crossrail project in London where 3 million tonnes of material excavated from the Crossrail tunnels was used to create a new wildlife habitat. This involved transporting the material by ship from East London to Wallasea Island, a wildlife project that the Royal Society for the Protection of Birds was developing in south-east Essex (Mellings & Limna, 2017).

To achieve sustainable development requirements, planners of infrastructure projects will increasingly need to look to landscape scale solutions. Earthworks expertise will play a big part in these initiatives. A recent example was Keyn Glas, which was a key part of a project to upgrade 15 km of the A30 trunk road in Cornwall, in south-west England (Oakman & Wood, 2022). It featured individual environmental enhancement projects on countryside up to 3km from the A30 and resulted in up to 250% net gain in biodiversity.

5. Preservation of topsoil and carbon sequestration

Topsoil (also known as "growing soil") is the top layer of the soil profile that is high in organic matter, micro-organisms and nutrients. Growing soils are a vulnerable resource and are fundamental to life on Earth but human pressures on soil resources are reaching critical limits. Recent European legislation has recognised the importance of topsoils and this will change the way they are used on construction sites. Careful soil management is an essential element of both sustainable earthworks and sustainable agriculture. The UK Department for the Environment, Food and Rural Affairs (DEFRA) Code of Practice for the sustainable use of soils on construction sites (DEFRA, 2009) summarises good practice on this subject. An updated version is due to be published in 2023. Stripping, stockpiling and replacing topsoils needs to be carried out carefully and in a way that enables them to continue their main function as growing mediums.

Topsoils hold much more carbon than the atmosphere (EA, 2019). Changes in land use and disturbance of topsoils can release a lot of carbon into the atmosphere and increasingly efforts are being made to reduce this. This will be an increasing challenge for earthworks construction as many earthworks projects require disturbance of topoils over large areas; and the need to limit this may be a tension with some other sustainability goals. The ability of topsoils to sequester carbon from the atmosphere will also become a function that will need to be increasingly considered on earthworks projects in the future.

6. Resilient earthworks

Resilience has always been a principal consideration in the design and operational performance of earthworks and earth structures. It is increasingly important because of the vital need for infrastructure that can withstand the impacts of climate change with more extreme and severe weather events. Recent studies of earthworks failures along UK's railway and road networks have found that most earthworks failures are due to heavy or extreme rainfall and drainage or porewater problems (Lane et al, 2020; Mair et al, 2021). For earthworks and earth structures, resilience needs to be considered holistically together with drainage and vegetation management. There are tensions between the requirements of decarbonisation (e.g. aiming for less material and steeper slopes) and resilience (e.g. slacker slopes) which will need to be addressed when designing earthworks projects.

The main stages in a typical risk-based resilience assessment framework for earth structures are set out in a paper by Codd et al (2023, in press). There are no commonly agreed standards in the UK for the management of earthworks assets but CIRIA has published best practice guidance on the management, condition appraisal and repair of infrastructure cuttings, embankments and drainage systems, CIRIA C591 (Perry et al, 2003a), CIRIA C592 (Perry et al, 2003b) and CIRIA C714 (Spink et al, 2013). Many infrastructure owners put considerable resources and efforts into the development of comprehensive earthworks management systems.

7. Conclusions

Over the next decade, we will need transformational changes in how we design and build our infrastructure. It will become imperative to minimise whole-life carbon, waste, use of natural resources and disturbance of existing soils, as well as to restore biodiversity and to be designed for climate-change resilience, together with other sustainability requirements. These goals are not wholly aligned and addressing their tensions requires a balanced cross-discipline approach to achieve the optimum solution. This includes earthworks, which is the most common aspect of civil engineering operations and which will play a major part in this transformation.

Earthworks construction is a relatively low-carbon activity due to the predominance of excavated natural materials. It is a highly mechanised activity and that equipment is currently powered almost exclusively by diesel fuel. Alternative, more sustainable, power sources and fuel types are being developed.

An earthworks strategy should be developed at an early stage in a project and has the potential to embed some of the largest sustainability opportunities for the project. It should be recorded in a Preliminary Earthworks Strategy Report and should be regularly updated as the design of the project develops. Geotechnical specialists are involved in the early tasks on projects and can guide the optimum sustainable earthworks strategy.

A good way to achieve many of the aims set out in the project earthworks strategy at planning and design stage is to adopt an "integrated earthworks design" approach whereby the necessary environmental mitigation earthworks are designed concurrently and collaboratively with the engineering earthworks and construction logistics requirements. Achieving as close as practicable to an earthworks balance is the key to this, just as it has been historically for earthworks in the past. Wherever practicable, this can provide the necessary environmental mitigation using excavated material. It can also create the potential for ecological gain through earthworks designed for habitat creation. The land take required for environmental mitigation earthworks needs to be carefully justified; and the impact on the carbon that is released through changes in land use and disturbance of topsoil also needs to be factored in (see below). This is an iterative process as the design develops and requires a multi-disciplinary team.

Topsoil (growing soil) holds much more carbon than the atmosphere. Changes in land use and disturbance of topsoil can release a lot of carbon into the atmosphere and increasingly efforts are being made to reduce this. Many earthworks projects require disturbance of topsoil over large areas; and the need to limit this may be a tension with some other sustainability goals. The ability of topsoils to sequester carbon from the atmosphere will also be a function that will need to be increasingly considered on earthworks projects in the future.

The new European standard on Sustainable Earthworks that is currently being developed aims to summarise the state-of-the-art in sustainable design and construction of earthworks, encourage best practice and encourage innovation.

8. Acknowledgements

The authors would like to thank Joanne Scott of BSI for permission to publish this paper. The views expressed in this paper are those of the authors themselves and not of Arup, Blackwell, BSI or CEN. Permission to reproduce extracts from British Standards was granted by BSI Standards Limited (BSI). No other use of this material is permitted.

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