Virginia Lawrence

What can engineers do to mitigate climate change?

Introduction

As we enter a new decade, we cannot deny that climate change is one of the most pressing issues of our generation. Many countries are falling short of their carbon emission goals for 2030 made under the Paris Agreement while the United States are requesting to officially be removed from this pledge[1]. With wildfires in Australia marking the start of the new year, there is no doubt that we have found ourselves in a climate emergency.

Climate change is an issue that spans many disciplines; not only the Sciences and Mathematics but economics and politics. To work towards a solution, we must consider the entire scope of the issue rather than focusing on solutions for small parts of a large problem. To exemplify an area where improvement must be made this essay focuses on the way engineers are working to mitigate climate change in the construction industry, particularly focusing on high-rise structures.

The carbon footprint of construction is often overlooked while building operations and production of materials are generating around 39% of carbon emissions globally[2]. The price of land in major cities is rising, and with it so do our buildings accommodating for the ever-growing urban population. To reduce these numbers, it is necessary to understand our current situation. New materials and buildings will be needed, but we must first consider how to reuse what we currently have.

What is sustainability?

In order to understand how engineers can make construction more sustainable, we must assess what sustainability is. In September 2015, the UN introduced 17 Sustainable Development Goals (SDGs) that countries should aim to achieve by 2030[3], some of which may be useful to judge the sustainability of construction. Goal 9 is to 'build resilient infrastructure, promote sustainable industrialisation and foster innovation'[3]; this involves considering carbon emissions from manufacturing processes, technological developments to increase energy-efficiency and the recognition that we must have innovation to industrialise without further polluting the Earth. Goal 11 considers sustainable urbanisation stating we must make cities 'safe, resilient and sustainable'; it is estimated that 68% of the world's population will live in urban areas by 2050[4], as many as 6.7 billion people[5], and with more construction to accommodate the growing urban population a push must be made towards sustainable materials and combatting air pollution. Goal 12 which addresses 'sustainable consumption and production patterns'[3]; this deals with resource efficiency, considering the principle of gaining the maximum value from our resources and designing things to be reused instead of using becoming landfill. This goal is the foundation for designing sustainable infrastructure and helps us measure how sustainable a building is; it also aptly marks a starting point for a circular economy.

How can we measure sustainability?

Assessing how well we are tackling an abstract objective will have to involve breaking down sustainability goals into quantifiable measurements. The Royal Institute of British Architects (RIBA) have created their own 'RIBA Sustainable Outcomes', adapted from relevant SDGs for architecture and found metrics to quantify the success of new buildings[6]. From Goal 7 – sustainable energy – RIBA use 'Net Zero Operational Carbon' calculated by $kWh/m^2/y$ (energy used per m^2 of building per annum) and $kgCO_2e/m^2/y$ (carbon footprint per m^2 per annum). From Goal 12 'Net Zero Embodied Carbon' which prioritises the reuse of buildings and responsible sourcing of resources; this can be calculated by TCO_2e (tonnes of CO_2 equivalent) embodied. Thus, we can give sustainable construction a number or scale used to compare new technology and developments to the past and set goals that can be followed.

The move towards a circular economy

Demolition of outdated buildings and infrastructure seemingly represents the process of innovation and urban development, but as cities grow it is no longer environmentally feasible to construct new buildings as soon as the last one is worn out. Following the green tagline of 'reduce, reuse, recycle', we should use what is already there to create new buildings instead of tearing down and adding to landfill. To reduce our consumption of concrete and steel, we must change our attitude that construction materials are disposable and should be thrown out once buildings are demolished.

Currently the construction industry is accountable for 60% of UK materials use and one third of all waste[7]. If we instead think of materials used in buildings as a temporary store, long outliving the structure it is part of, we may create new buildings from the 'waste' of the old.

The idea of a circular economy (CE) is to reuse resources until no more value can be garnered from them thus reducing waste and the environmental impacts of generating new resources. To move towards a CE would mean minimising waste in the building process and taking into consideration the use of these resources after the building is demolished. This would help work towards net zero embodied carbon goal and could be quantified by carbon emissions saved by reusing entire parts of buildings. This must be addressed from the design stage of the building as parts may be of use in the future meaning high quality production of resources that retain their valuable characteristics must be prioritised over cheaper options that will not be reusable for further construction projects. Changing attitudes to innovation is crucial to increase the take up of sustainable construction and so more work needs to be done to publicise the benefits and need for sustainability in this sector. The London Plan, an economic and environmental plan for London over the next 20 years set out by the Mayor of London and Corporation of the City of London, has already adapted to include 'promoting a more circular economy that improves resource efficiency' and 'encouraging waste minimisation'[8]; this provides a clear pathway to work towards Goal 9.

The question is then raised about the feasibility of reusing buildings: how could we possibly find the resources we are looking for in cities full of demolition and construction at every moment? Engineers are developing solutions to logistical issues with circular construction by cataloguing resources currently in use. Dutch architect Thomas Rau is creating a master database of all the materials at use in buildings in Amsterdam[9]. "Waste is simply a material without an identity" he says. He has also developed 'material passports' that define every element in a construction project based on its material characteristics allowing it to be taken and reused when needed, making reuse of materials more accessible and more cost efficient than producing new ones. In another effort to create a circular use of resources, architect Anders Lendager has finished a residential development in Copenhagen, a city pledging to be carbon neutral by 2025[10]. 'Resource Rows' shown in Figure 1 use panels of brickwork taken from the demolished Carlsberg brewery whose bricks would have otherwise been thrown to landfill[9].

Figure 1: Resource Rows. Photo by Mikkel Strange

The market for greener residential buildings has shown increasing demand with the green housing development being rented out more quickly than any other housing scheme in the city seeing a 50-60% reduction in CO_2 emissions compared with conventional construction.

The need for new materials

Reusing materials from past construction projects may not be the only way a circular approach to the materials industry can be implemented. In the short term, we can progress a long way simply by reusing more efficiently but for the most effective solution we must also utilise the materials industry to plan for the new construction that is needed to accommodate the growing population.

Even construction using recycled resources will require some new materials, especially when added to the need for more domestic and commercial construction due to population growth. Material scientists are developing materials with reduced carbon footprints to compete against the unsustainable giants of the construction materials market: concrete and steel. Their increased energy efficiency will be necessary to achieve net zero operational carbon. The foundations of buildings are traditionally built from cement, a strong, easily made and reliable material. However, cement production is responsible for generating 4 – 5% of global CO_2 emissions[11], the third highest producer after transport and energy generation. Not only is heat produced by fossil fuels needed to manufacture cement but the calcium carbonate (limestone) used in the production process thermally decomposes to produce CO_2 and lime.

In 2010, London based company Novacem pioneered the movement towards greener cement[12] by discovering a way to replace Portland cement – used to bind concrete – with a magnesium oxide material that when mixed with water formed carbonates that strengthened the cement. This avoided the use of limestone which was cause for 70%[2] of CO_2 emissions in old style cement. However, Novacem could not raise enough funds and in 2012 was liquidated. Another common cement alternative, pulverised fly ash (PFA) made from waste from coal power stations is produced at around 500Mt per annum[13] but relies on waste from a polluting industry and has less initial strength than cement and so is not feasible as a large-scale replacement. Similarly, Ferrock, made from the waste steel of the steel industry containing 95% recycled material[14] may be a more cost-efficient way to reduce the carbon footprint of construction materials. It is carbon neutral, absorbing CO_2 as a part of its drying process and is stronger than concrete lending itself to use in foundations. While the operation carbon is low, Ferrock relies on being a waste product of the steel industry which is itself polluting and not sustainable in the move towards a circular economy.

While these materials are paving the way towards innovation in the materials industry, they have little experience in real construction projects. Without a strong incentive the construction industry is reluctant to change and so there must be more proof of the benefit of using these newly developed materials. One sustainable material that is starting to be utilised in construction world-wide dates back to further than any traditional building materials today: wood.

The rise of 'plyscrapers'

London keeps getting taller with seven new skyscrapers currently under construction, the tallest being 22 Bishopsgate which plans to rival the shard at 294m high[15]. These new developments require masses of steel and concrete to build causing them to have large embodied and operational carbon footprints. By 2050, the United Nations estimate that 68% of the world's population will live in urban areas[4], a 27% rise from 2018. This will require new, greener building technology than we are currently using if we are to reduce the carbon footprint of construction.

Figure 2: Stadthaus, Hackney. Photo by Will Pryce

Shown in Figure 2, Stadthaus in Hackney, London is a 9-storey apartment building made of timber built in 2009[16]. Pioneering the way into timber structures it demonstrates some key advantages to wooden high rises. Wood locks approximately 1 ton of CO_2 per m^3 making it the ideal resource for carbon neutral construction and low embodied carbon goals. Stadthaus is calculated to store around 186,000kg of CO_2 in its framework[17]. Undoubtedly wooden buildings have their draw backs; after the great fire of London in 1666 the city was rebuilt with stones and mortar for fear of a fire spreading again, but the engineers behind these ‘plyscrapers’ are developing new ways to improve the characteristics of wood to make them more suitable for construction. Both laminated veneer lumber, as strong as concrete, and laminated timber have been around for years and are used for columns and beams due to their strength. Cross laminated timber (CLT) is a new development claiming to be as strong as the steel used in skyscrapers today; its criss-crossed layers are bound by fireproof glue and it does not share weaknesses common in wooden infrastructure such as warping and weak spots as they are combatted by the differing grain directions[18]. However, CLT is a fairly new material and so has relatively little testing meaning we are unsure of its capabilities; currently there are only a small number of CLT manufacturers, and they are mainly located in alpine countries such as Austria leading to a high transportation cost and thus embodied carbon. If CLT production spreads throughout Europe and the USA it could soon challenge steel and concrete in the market for construction resources. As the environmental cost of building is increasingly taken into account engineers will be crucial in designing and implementing sustainable materials for construction.

Economic and legislation challenges

To have economic progress there must be an incentive for change. Using material passports, we can calculate the value of materials in a building that can be reused, reducing cost of production of new materials and cost of disposal of waste. A study for the Metropolitan Region of Amsterdam calculated that the 2.6 tonnes of building materials released from demolition, that would previously have entered landfill, could have a value of €688 million[19]. If we begin the move from seeing material deposits in buildings as waste to reusable materials that will reduce future costs, the construction industry will want to follow.

Current timber architecture and reused building materials are in line with building regulations and surpassing operational carbon goals. However, national legislation is behind in encouraging producers to change. While they are required to show that materials are responsibly sourced there is little else done to ensure the sustainability of buildings being constructed. Embodied carbon assessments are increasingly being used to evaluate the sustainability of construction and in the design stage to select materials; although currently these assessments are voluntary, they may become legislation in the future to ensure the construction industry is on track to meet climate targets set by the government[20]. A lot can be done already but having the support of the government with legislation requiring buildings to meet certain requirements will make change swifter and not leave companies behind. Engineers will need to work with politicians and industry professionals to demonstrate the need for and ability to change our construction emissions.

Conclusion

Engineers have a large scope when dealing with climate change and so are able to consider large scale solutions. Trying to be too specific may decrease efficiency and so creating plans that cover a broad area such as construction is necessary to find an effective solution. For a circular economy aiming to maximise efficiency this is invaluable. When looking at construction, we can consider what can be reused, what must be innovated and how these changes can be implemented. In the short term, a lot can be done with resources we already have, focusing innovation on efficient ways to reuse materials rather than create more. However, as the population grows and new resources are needed, new materials are needed to replace concrete and steel and must become more mainstream. Incentives for change through legislation and raising public awareness are necessary to create the colossal shift away from traditional building materials and towards a more sustainable future for construction.

Bibliography

[1] Leahy, S. 2019. *Most countries aren't hitting 2030 climate goals, and everyone will pay the price.* National Geographic.
<https://www.nationalgeographic.com/science/2019/11/nations-miss-paris-targets-climate-driven-weather-events-cost-billions/>
[Accessed 6 Jan 2020]

[2] Architecture 2030. 2019. *Why the building sector?* Architecture 2030.
<https://architecture2030.org/buildings_problem_why/>
[Accessed 9 Jan 2020]

[3] UN General Assembly. 2015. *Transforming our world: the 2030 Agenda for Sustainable Development.* <https://www.refworld.org/docid/57b6e3e44.html>
[Accessed 13 Jan 2020]

[4] United Nations. 2018. *68% of the world population projected to live in urban areas by 2050, says UN*. United Nations.
<https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>
[Accessed 7 Jan 2020]

[5] United Nations. 2017. *World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100.* UN Department of Economic and Social Affairs.
<https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html>
[Accessed 13 Jan 2020]

[6] Royal Institute of British Architects. 2019. *RIBA Sustainable Outcomes Guide.*
<https://www.architecture.com/-/media/GatherContent/Test-resources-page/Additional-Documents/RIBASustainableOutcomesGuide2019pdf.pdf>
[Accessed 13 Jan 2020]

[7] UK Green Building Council. 2019. *Build circular economy thinking into your projects.* UKGBC.

[8] London Assembly. 2017. *Policy SI7 Reducing waste and supporting the circular economy.* London Assembly. <https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-9-sustainable-infrastructure/policy-si7-reducing-waste>
[Accessed 16 Jan 2020]

[9] Wainwright, O. 2020. *The case for never demolishing another building.* The Guardian.
<https://www.theguardian.com/cities/2020/jan/13/the-case-for-never-demolishing-another-building>
[Accessed 15 Jan 2020]

[10] Cities. 2019. *Inside Copenhagen's race to be the first carbon neutral city.* The Guardian.
<https://www.theguardian.com/cities/2019/oct/11/inside-copenhagens-race-to-be-the-first-carbon-neutral-city>
[Accessed 15 Jan 2020]

[11] Greenspec. 2019. *The Environmental Impacts of Concrete.* Greenspec.
<http://www.greenspec.co.uk/building-design/environmental-impacts-of-concrete/>
[Accessed 6 Jan 2020]

[12] Majcher, K. 2015. *What happened to green concrete?* MIT Technology Review.
<https://www.technologyreview.com/s/535646/what-happened-to-green-concrete/>

[Accessed 6 Jan 2020]

[13] Allwood, Cullen. (2012). *Sustainable Materials with both eyes open.* Cambridge UIT

[14] Build Abroad. 2016. *Ferrock: A Stronger, More Flexible and Greener Alternative to Concrete?* Build Abroad. <https://buildabroad.org/2016/09/27/ferrock/>
[Accessed 7 Jan 2020]

[15] Morby, A. 2019. *Six tower plans to change London's skyline by 2026.* Construction Enquirer. <https://www.constructionenquirer.com/2019/01/03/six-planned-towers-to-change-london-city-skyline-by-2026/>
[Accessed 7 Jan 2020]

[16] Gorvett, Z. 2017. *'Plyscrapers': The rise of the wooden skyscraper.* BBC. <https://www.bbc.com/future/article/20171026-the-rise-of-skyscrapers-made-of-wood>
[Accessed 7 Jan 2020]

[17] Kuittinen, M. 2015. *Carbon storage in wood-based buildings.* Metsä Wood. <https://www.metsawood.com/global/news-media/articles/Pages/carbon-storage.aspx>
[Accessed 7 Jan 2020]

[18] The B1M. 2017. *What is Cross Laminated Timber (CLT)?* Youtube. <https://www.youtube.com/watch?v=YuAya0hRjwU>
[Accessed 8 Jan 2020]

[19] Opray, M. 2019. *On the journey to a circular economy, don't forget your materials passport.* Metabolic. <https://www.metabolic.nl/news/circular-economy-materials-passports/?utm_source=facebook&utm_medium=referral&utm_campaign=materialspassport>
[Accessed 16 Jan 2020]

[20] HM Government. 2016. *Conservation of fuel and power: Approved Document L.* GOV.UK <https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l>
[Accessed 16 Jan 2020]