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Comparing the eCO2 Emissions Effects of Two Slab-on-Grade Screeding Methods

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While previous research has been conducted on concrete production to improve sustainability while retaining durability and constructability, this research focuses on construction practices in slab-on-grade screeding and how project management decisions can impact eCO2 emissions. A comparative life-cycle assessment of manual and laser screed was performed in a traditional 100,000 SF slab with 6" thickness. The study aimed to determine the effects of a slab-on-grade's equivalent embodied carbon (eCO2) in commercial projects. Two embodied carbon calculators (EC3 and Green Badger) were used to examine the differences between the two methods. Industry professionals provided actual commercial project data to determine the impact of laser screed compared to manual screeding. This study found that laser screeding reduced schedule, workforce requirement, and concrete waste for the slab-on-grade installation. These results demonstrate an important reduction in embodied carbon due to reduced worker transportation and concrete manufacturing emissions. The findings also indicate that project managers can improve the environmental sustainability of their projects by using alternative techniques, such as laser screed equipment, compared to manual screeding.

Key Words: Concrete, Slab-on-Grade, Screeding, Life-Cycle Assessment, Embodied Carbon

Introduction

The use of concrete produces significant global emissions. Implementing new strategies to improve the efficiency of concrete placement has become a goal for the construction industry. In particular, the production of cement used in concrete causes 5% of global emissions, and the need to improve the environmental sustainability of concrete is crucial to lower global eCO2 emissions (Hooton & Bickley, 2014). Life-cycle Assessment (LCA) studies are becoming more common in an effort to help industry professionals and researchers evaluate the effects of different materials and construction practices on a project's embodied carbon. This strategy lets project stakeholders understand how their decisions can be altered to achieve more sustainable solutions. Concrete is used in all construction sectors, and an assessment of the material flow of concrete showed that the United States produces

400 metric tons of concrete a year (Man-Shi, 2005). In addition, the industry has researched different strategies to improve the environmental sustainability of concrete, including the production process. For example, substituting cement, the primary binder in concrete, with alkali-activated binders could replace the use of Portland cement by 80% (Adesina, 2020). Evaluating concrete components and finding more sustainable alternatives can reduce the eCO2 emissions without reducing the quantities produced.

The construction process can be more sustainable while retaining durability and constructability. For example, concrete production can be improved by optimizing inputs, supplementary cementing material use, and increased durability (Hooton & Bickley, 2014). These improvements focus on the product and end-of-life stages of a life-cycle assessment. Concrete with improved durability can lengthen the lifespan of structures and lower embodied carbon. Changing concrete mixes has been a focus of previous studies because of the significant number of emissions produced from concrete production. For example, a study examined the effects of fiber-reinforced polymer on concrete beams and found that durability was improved in crack development (Cao et al., 2015). Fiber reinforcement can lengthen the time for beam or structure replacement.

However, current construction practices can also be improved to reduce the amount of concrete used, resulting in lower embodied carbon for construction projects. Slab-on-grade production is an opportunity for enhanced sustainability in the construction industry. Slab-on-grade construction has become a common occurrence in commercial construction due to the advantages of reduced construction times and architectural flexibility (Thakur & John, 2019). Improvements in the process of slab-on-grade construction can provide projects nationwide with strategies to reduce their eCO2 emissions. Project management can help educate those involved on the means and methods of a project, reducing emissions related to concrete use. Additional research in construction practices could provide the industry with other strategies to improve its impact on carbon emissions.

In response to this need, this study compares how two concrete screeding methods for slab-on-grade construction affect eCO2 emissions. The effects on embodied carbon of slab-on-grade execution were examined to inform industry professionals about more sustainable practices. Based on the preliminary understanding that screeding methods affect efficiency and quality, differing embodied carbon amounts are expected to exist. This study compares the effects on eCO2 emissions from manual and laser screeding.

Literature Review

Construction is responsible for 40% of global energy-related emissions, so it presents an opportunity for emission reductions through different project management decisions (Chen et al., 2023). Concrete is a large portion of construction emissions because it accounts for 5% of global eCO2 emissions (Hooton & Bickley, 2014). This impact has led researchers and professionals in the construction industry to explore methods to reduce the embodied carbon of concrete. Common methods of improving the sustainability of concrete are the manufacturing process, material inputs, and construction process. Another form of carbon emissions in the construction industry is workers' transportation methods to the project (e.g., transportation). Worker's transportation is not a significant source of emissions in the construction industry compared to other producers of embodied carbon (Moncaster & Symons, 2013). If reduction in worker transportation is the only focus, project managers may not reach their desired reductions in emissions.

To understand current methods used to analyze the embodied carbon in construction, this study was based on the article "Life Cycle Assessment in Construction Sector: A Review" to explore the importance and methods of life-cycle assessments (Buyle et al., 2013). The authors found that a technique that can improve the LCA calculations is using average values for LCA inputs to improve the comparability of reviews (Buyle et al., 2013). When specific values are only used to examine a process, it limits the potential ability of the construction industry to draw conclusions about their projects. A recent life-cycle assessment of concrete in the US utilizing a cradle-to-gate scope found that emissions calculations can change when using data from independent facilities (Hottle, et al., 2022). Reviewing the emissions from independent facilities provides a researcher with information on the impact of location and manufacturer selection. Another factor that impacts an LCA is the definition of scopes. LCAs' scopes that encompass product production and construction are called "cradle to site" and include substages A1 (raw material extraction), A2 (transport of materials), A3 (manufacturing), A4 (transportation to site), and A5 (construction) (Ming & Wang Esram, 2021). This scope of an LCA does not encompass the building's life cycle, for it does not include the use or end of building life in the assessment. Reducing the scope of an LCA allows researchers to examine specific project scopes to focus on particular variables. The assessment of screeding methodology focuses on the "cradle-to-site," which allows for examining construction techniques but excludes impacts on the use of end-of-life on an LCA. Finally, the impact measurement must be selected and stated so that the results are consistent with the included variables. eCO2 measures embodied carbon from building materials and the construction process (Syngros et al., 2017). This is a measurement that encompasses all the emissions related to a specific scope of a project, for if an assessment only examined emissions from construction, it would exclude emissions from the manufacturing of materials.

The use of a carbon calculator is increasing to support LCAs that can assist in achieving green certifications and methods to reduce embodied carbon. Embodied carbon calculators have been shown to provide conclusions on strategies to improve the sustainability of projects, but they can provide limitations as each program utilizes different calculation methods (Jackson & Brander, 2019). As the construction industry has not set a standard for embodied carbon calculator use, LCAs utilizing this tool should be used as a basis for understanding that variations between calculators may be present. This tool provides the construction industry with another source to identify how different material selection, manufacturing, and construction methods can change carbon production related to a project or process. The used calculator should also be stated to ensure that the industry can research the process further because this can provide conclusions on differing LCA analyses.

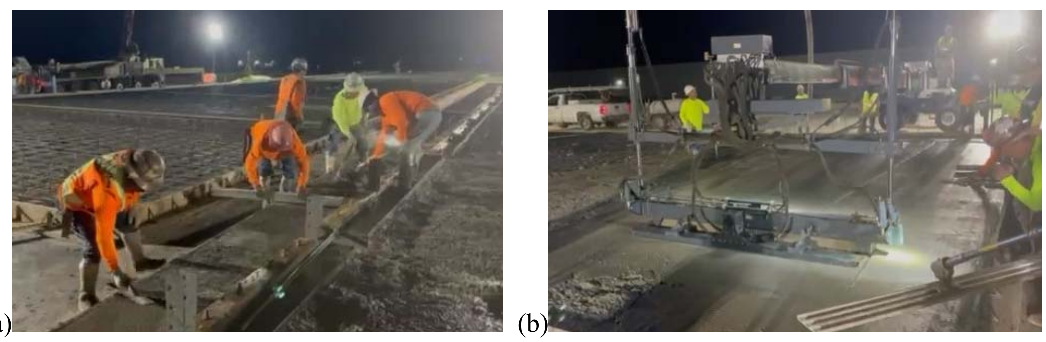
Project managers are stakeholders who can impact the effects of the construction industry on surrounding communities and the world. Project managers can approach construction with a triple constraint sustainability mindset that encompasses the economic, environmental, and social impacts throughout their careers (Stanitsas et al., 2021). While this research on concrete screeding methods only examines the ecological impact, the industry can also examine social and economic impacts, and this approach allows for a holistic approach that evaluates the impact of all stakeholders. Project managers can use new technology training to improve a site's sustainability by informing incoming subcontractors on improved methods and offering incentives for using more sustainable practices (Robichaud & Anantatmula, 2011). The goal of producing a sustainable project can be accomplished by utilizing and including all stakeholders and offering subcontractors advice and incentives on sustainable practices.

In particular, screeding methods are used after pouring concrete to level the slab to the desired grade and remove excess concrete. The most widely used screeding method in the construction industry is manual screeding. Manual screeding is typically performed by two workers who pull a screed over the discharged concrete until the desired results are achieved (Albers et al., 2004). The selected method of screeding is based on a project manager's decision. The size of the pour, project budget, and required or desired result are factors that can impact selection.

Research into the improved sustainability of concrete screeding has focused on the concrete mixes to limit the onsite equipment and workforce. An evaluation of the sustainable product performance score (SPPS) found that self-compacting cement screed has a lower impact than traditional screeding methods (Artelt & Lukas, 2020). The research on self-compacting cement showed that projects can improve their impacts on the environment, stakeholders, and project economics through concrete mix selection. While this research provides options for some projects, slab-on-grade projects may not have access to or the ability to use self-compacting cement screed. This comparative study of laser and manual screed aims to provide insight for project managers on options to lower the eCO2 emissions from their projects.

Research Design

This study began with analyzing previous publications related to embodied carbon in concrete construction, current methods for LCA, and project management practices to improve concrete sustainability. The comparative slab-on-grade process assessment used a quantitative methodology. A standard concrete slab-on-grade pour was selected, and the impact on an LCA from manual screed techniques compared to laser screed equipment was performed. An example of manual screeding can be seen on the left and laser screeding on the right of Figure 1. This assessment included embodied carbon in stages A1-A5 of a life-cycle assessment focusing on raw material extraction, manufacturing, transport to the construction site, and installation. The measurement for embodied carbon used is equivalent CO2 (eCO2), which measures the global warming potential of weighted greenhouse gas emissions. By comparing standard concrete pouring methods to the new equipment, one can determine the variations in embodied carbon possible through project management practices.



(a) (b)

Figure 1. Manual (a) and laser (b) screeding examples for slab-on-grade construction

The steps included in this research process are provided below.

1. Literature review
2. Selection of base project variables for assessment
3. Selection of carbon calculator software
4. Analyze the carbon outputs from standard methods and use of laser screed equipment
5. Compare findings from the pour process assessment to identify differences in embodied carbon

Base Pour Selection

This study analyzed the effects of laser screed equipment on the embodied carbon of a slab-on-grade pour. Industry professionals from supplier X of laser screed equipment were interviewed to determine a subject pour variables based on projects and companies using their equipment. The subject pour selected was a 100,000-sf slab-on-grade pour with a depth of 6 inches. This study did not include activities and materials that were not changed from the analyzed methods. Concrete was the only material used because other materials, such as rebar, footers, and miscellaneous products, were not changed due to laser screed use. Mix design with a compressive strength of 4,000 psi was collected from industry professionals (Strong, 2022). Transportation distances and methods were given by supplier X of standard construction projects using their equipment. The miles were used to calculate the average emissions produced per mile from the workers' transportation. Crew sizes were found using data from previous projects using standard pour methods and laser screed projects. Table 1 shows the base pour inputs.

Table 1

Base concrete pour inputs

Variable	**Manual Screed Pour**	**Laser Screed Pour**
Working Days	13 Days	5 Days
Number of Employees	20 Tradesman	10 Tradesman
Average Transportation Distance	60 Miles	60 Miles
Percent of Employees Using Cars	85%	85%
Percent of Employees Using Bus	3%	3%
Percent of Employees Using Transit Rail	2%	2%
Percent of Employees Using Commuter Rail	2%	2%
Percent of Employees Biking or Walking	8%	8%
Concrete Quantity	1897 cy	1888 cy
Concrete Waste Factor	2.45%	2%

Software Assessment Tools

Publicly available programs were used to analyze the embodied carbon of the variables selected. Embodied carbon calculators can be used to identify potential emission reductions for some construction projects (Jackson & Brander, 2019). This study used the Embodied Carbon in Construction Calculator, EC3, to analyze the effects of the differing concrete quantities. This program analyzes the embodied carbon of a product from raw material extraction and manufacturing. The EC3 tool was built to provide values on the eCO2 associated with building materials for owners, designers, engineers, and contractors ("Embodied Carbon", n.d.). This tool allows the construction industry to analyze the sustainability of selected materials and make decisions to reduce the project's embodied carbon.

Mix designs and quantities provided by industry professionals were entered into the system to assess the embodied carbon quantities possible for the subject project. This study used the realized carbon emission instead of the achievable to limit the variables affecting the embodied carbon. The realized emissions show the emissions that can be expected from a standard concrete plant, and the achievable emissions show the emissions that concrete plants may produce with more sustainable practices.

Green Badger's program was used to analyze the effect of employee transportation to and from the site and integrate the caculations from the EC3 tool. Green Badger is a project management software founded by Tommy Linstroth, developed to help project stakeholders record LEED documents for certification ("Green Badger", 2021). For transportation carbon emissions, this study separated employee transit by type, which provided data on how shorter project duration and smaller crew amounts affected the concrete installation's life-cycle assessment. Separate projects were created for the standard and laser-screed concrete pours to examine the total effect laser-screed equipment can have on slab-on-grade construction. The program can then be used to upload the realized emissions to combine the total emissions. This allows for the emission sources to be compared from contribution to total project emissions.

Results and Discussion

Transportation

This study showed that the laser screed equipment can reduce the direct embodied carbon of a project regarding employee transportation. The reduced labor requirement and project duration reduced the total amount of miles traveled to reach the site. If the project retained the same number of employees but reduced the duration by 62%, the total miles would be reduced by the same proportion. This difference leads to direct carbon emissions being reduced. The reduction of labor produced the remaining 19% less in total miles traveled, leading to a total reduction of 81% in miles traveled. This result shows that schedule reduction is the primary benefit of laser screeding when analyzing emissions from worker transportation. Table 2 shows the reduction in worker transportation in miles.

Table 2

Employee Transportation Mileage Comparison

Transportation Type	Manual Screed Pour	Laser Screed Pour
Passenger Car	2988 Miles	575 Miles
Commuter Rail	54 Miles	10 Miles
Transit Rail	71 Miles	14 Miles
Bus	111 Miles	21 Miles

An original study assumption was that there was no expectation that workers' commutes would significantly impact the total embodied carbon of a slab-on-grade concrete pour. The literature review yielded similar results because concrete is associated with large amounts of eCO2 (Hooton & Bickley, 2014). The Green Badger program assessment showed that the total tonnes of eCO2 produced from worker transportation for the manual and laser screed pours was 1 tonne of eCO2 and 0.1 tonnes of eCO2, respectively. These amounts would be changed due to the location of the construction project; projects are not always accessible by public transit and may require workers to drive passenger cars to the project. Passenger cars produce more emissions per passenger than public transportation methods (Kennedy, 2002). This commute approach would lead to a more significant reduction in emissions produced from employee travel when comparing a slab-on-grade pour screeded with standard techniques compared to laser screed equipment. On the contrary, access to public transportation will lead to a less significant reduction in direct emissions. Therefore, project managers should consider these findings, but must conduct assessments related to their specific projects.

Concrete

The results of this study showed that reducing waste from laser screed technology can improve the environmental impact of concrete slabs. The data provided by industry professionals at Company X showed that the laser screed technology resulted in a .45% reduction in excess concrete due to leveling errors compared to manual screeding. Using laser screed equipment resulted in the 6"

100,000 sf slab requiring 8.46 cy less concrete. This value came from the required concrete of 1,852 cy. The change in quantities is related to the waste factors given for manual versus laser screeding.

The EC3 tool was used to find the tonnes of eCO2 produced from the differing quantities of concrete necessary for the manual and laser screed slab-on-grade pours. The total reduction of embodied carbon from concrete production using the laser screed equipment was 2.9 tonnes of eCO2. The total eCO2 produced from concrete production and transportation for the slab-on-grade project was 665.5 tonnes for the manual screed and 662.5 tonnes for the laser screed. This result shows that the laser screed produced 3 fewer tonnes of eCO2 than the manual methods. The proportions found are expected to be similar when comparing different sizes of slab-on-grade pours; depending on variations of variables such as the pours' complexity or location, the percent change may not be constant. To realize the benefits of the laser screed equipment, the amount of concrete ordered must be reduced to account for reduced waste, for if the same concrete quantity is ordered, there will be no reduction in eCO2 emissions for the slab-on-grade construction.

Combined Results

The authors analyzed the change in embodied carbon from employee transportation and concrete production and transportation by combining the data in the Green Badger program. As shown in Table 3, the slab-on-grade pour using manual screeding had a total of 666.5 tonnes of eCO2, and the laser screed slab-on-grade pour produced 662.6 tonnes of eCO2. These total amounts included the embodied carbon associated with the production and transportation of concrete along with worker transportation. This research showed that the use of laser screed equipment produced a reduction in eCO2 of 3.9 tonnes. For smaller slab-on-grade pours, purchasing or renting laser screed equipment may not be reasonable based on the project budget, but larger slab-on-grade pours can offset equipment costs with reductions in total concrete orders. A standard laser screed rental is $2,800 a day or $0.14 per square foot (Laser Screed, 2023). This additional cost can be offset using tax credits from the United States for clean energy investments.

Table 3

eCO2 Emissions – Slab-on-Grade (100,000 sf by 6" depth)

eCO2 Producer	**Manual Screed Pour**	**Laser Screed Pour**
Concrete	665.5 tonnes eCO2	662.5 tonnes eCO2
Worker Transportation	1 tonne eCO2	.1 tonnes eCO2
Total	666.5 tonnes eCO2	662.6 tonnes eCO2

The combined data showed that employee transportation was a small proportion of total emissions because it was only responsible for less than 1% on both the manual and laser screed slab-on-grade pours. The literature review also showed that workers' transportation produces less eCO2 than other factors in the construction industry. The reduced worker transportation caused by using laser screed equipment resulted in 23% of the total reduction in eCO2 produced compared to manual screeding. While concrete was the main source of eCO2 in this research, the reductions in transportation emissions were still significant savings, comparatively.

Conclusions

This study compared the embodied carbon produced in slab-on-grade production when using manual and laser screeding methods. The results showed that laser screed equipment can reduce eCO2 produced by concrete output and worker transportation. Most reductions in eCO2 production resulted in less waste in concrete when using the laser screed equipment, leading to the project manager ordering fewer quantities of concrete for slab-on-grade pours. The remaining savings were found from reduced worker requirements, reduced project duration, and less transportation required.

While previous research has focused on concrete material selection and production, this study focused on a project management decision that can readily be implemented on projects. Project managers can use the information presented to understand the benefits of laser-screed equipment. This study's results could help convince stakeholders that there are multiple benefits to investing in new techniques in concrete screeding; reduced schedule, worker requirements, and concrete waste offset the equipment cost. This research project also showcases the capabilities of new publicly available tools to perform life-cycle assessments on construction projects. The EC3 tool provided information on the embodied carbon of concrete, and the Green Badger software provided information on worker transportation emissions and compiling the material emissions from the EC3 tool. Industry professionals and students should be educated on publicly available tools to perform LCAs to increase the understanding of their decisions on the eCO2 of their current and future projects.

If an LCA encompasses more scopes, the risk of unaccounted eCO2 production is reduced. The output of laser screed equipment also has an embodied carbon associated with it. The embodied carbon of laser screed equipment includes procuring materials, assembly, and transportation. It can be argued that this embodied carbon may be partially included in the building's LCA, depending on the scope definition. As laser screed equipment may not be present at a project location, the eCO2 emissions produced for procurement may result in a less sustainable outcome. This research did not include the embodied carbon associated with the production and transportation of laser screed equipment; this aspect of the method certainly needs attention. This is a limitation of this study because other LCAs' may set differing parameters that can produce varying findings.

Further research should be pursued to advance our understanding of these results. For instance, project location may affect the availability of laser screed equipment or offset reduction in eCO2 emissions due to longer travel distances. This would help project managers analyze the most sustainable method for their project. Future research can also include analyzing what sizes of projects are optimal for different screeding methods when analyzing embodied carbon. Complexity (e.g., different corners and details) may affect the productivity of screeding methods and produce recommendations for project managers. This study aimed to analyze the effects on embodied carbon by comparing manual and laser screeding methods, and the findings of improved sustainability using laser screed can be used by project managers to determine their slab-on-grade construction process.

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