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How Aware and Active is the Swedish Building and Real Estate Sector in Climate-Smart Concrete?

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Abstract - *Carbon dioxide has long proven to be one of the greenhouse gases that affects our planet's climate and environment. With the forthcoming European Union goals and Sweden's own net-zero goal, it is required that the building and real estate sector works with climate-smart materials to construct future buildings. The net-zero goal by 2045 requires a common effort from all companies to find innovative solutions in order to reduce carbon dioxide emissions sharply. This study investigates how aware and active the building and real estate sector is in climate-smart concrete (CSC) through a survey and comparison of environmental product declarations (EPDs). Climate-smart is a term for concrete that contains a lower percentage of Portland cement clinker than traditional concrete. This research aims to examine how far the development has taken place and to evaluate how the market has adopted the newly available products. It is also assessed which alternative additive materials are the most common as well as advantages and disadvantages of the CSC. A questionnaire is created, and the survey is sent out to companies. A comparison is made between three different EPDs of the CSC and two references for concrete with the ordinary Portland cement clinker. Reference concrete 1 is a standard value, and reference concrete 2 is an EPD value. A reference building is used to calculate the volume and weight of its utilized concrete. The three types of the CSC are compared with the reference concrete 1, and the results show a carbon dioxide reduction of 29.3%. However, the comparison of these three types of the CSC with the reference concrete 2 demonstrates a carbon dioxide reduction of 2.8%. In addition, it is concluded that the future will require the building and real estate sector to invest time and training to work with the CSC further.*

Keywords - *climate-smart concrete, environmental product declaration, fly ash, carbon dioxide emission, greenhouse gas, Portland cement, additive material.*

I. INTRODUCTION

Concrete is an essential building material for our society thanks to its good durability, proper formability, and long working life. These properties make it difficult to replace concrete with any other materials having a limited extent. Concrete also has other good features such as fire resistance, heat resistance, and sound insulation. It is one of the oldest building materials that enables the construction of buildings, bridges, roads, and other infrastructures. Since concrete is an important building material used worldwide, it is necessary to examine its climate impact. Cement is the main component of concrete that gives it high strength. Research attempts indicate that the cement industry is responsible for 5%-8% of the world's carbon dioxide emissions. Today, the climate impact of a material is calculated by evaluating the material's emissions of greenhouse gases and climate change [1].

By 2050, the European Union (EU) aims to become climate neutral, i.e., all the European countries will have a net-zero emission of greenhouse gases. The Europe's goal is a change that is both urgent and crucial for the future of our planet. The Sweden's climate goal states that the country must have achieved a net-zero emission of greenhouse gases by 2045. The net-zero goal means that the emissions from Sweden must be at least 85% lower in 2045 than in 1990. Additionally, there are complementary measures for the remaining emissions.

The Swedish building and real estate sector accounts for an environmental impact that corresponds to 10%-30% of the total environmental impact from the Swedish production. Further, the sector contributes to the emissions from other countries through the import of building products. This brings great responsibility for the building industry regarding environmentally smart material choices, which also aims to meet the housing need by 2025. For the cement industry, this means greatly reducing, or preferably completely, the carbon dioxide impact that occurs during the cement production to achieve the net-zero goal. This ambitious goal signifies that the legislation needs to be changed in line with the environmental requirements that are set to ensure that the goal is met.

The Swedish concrete industry currently faces two major challenges as to achieve the goal of a climate-neutral Sweden and to build large numbers of infrastructures and houses. Several research development works have been ongoing on climate-smart concrete (CSC). The potential position of geopolymers as an element for a sustainable concrete industry was discussed by Duxson et al. [2]. Yunsheng et al. [3] prepared a green reactive powder concrete with compressive strength of 200 MPa using composite mineral admixtures, fine natural aggregates, and short and fine steel fibers. A pumice-lime binder was proposed by Nozahic et al. [4] as an alternative to the traditional cement or lime-based solutions. Ondova et al. [5] studied the possibility of utilizing fly ash to replace cement in concrete pavement. Müller et al. [6] outlined methods to evaluate and decrease the environmental impact of concrete, and means to enhance its performance. The results of an investigation on self-compacting concrete made with stainless steel reducing slag were reported by Sheen et al. [7]. The influence of the curing time on the fracture toughness of concrete produced with different concentrations of coal fly ash was assessed by Golewski [8]. Alani et al. [9] examined the effect of incorporating ultra-fine palm oil fuel ash with the shredded recycled waste bottle on the properties of ultra-high-performance concrete. The substitution of Portland cement in mortar and concrete mixes with up to 40% of the highly-reactive pozzolanic diatomaceous earth with abundant deposit was analyzed by Li et al. [10]. The mechanical properties and hydration of green concrete, which was made from ground granulated blast-furnace slag (GGBS), desulfurization gypsum, and electric arc furnace reducing slag as cementitious materials were investigated by Li et al. [11]. Khan et al. [12] presented the design of green concrete by partially replacing cement with fly ash. Zhang et al. [13] focused on the feasibility of developing a green concrete product from municipal solid wastes incineration residues. The effects of varying the water-to-cement ratios and soaking time of glass powder on the activation of the pozzolanic reactivity and the mechanical properties of green concrete were evaluated by Elaqra et al. [14]. However, the CSC is still an unknown issue in comparison with the traditional concrete that contains Portland cement.

This study deals with how the Swedish building and real estate sector works with the CSC. Also, in cases where the sector works with the CSC, the sector's awareness of the net-zero goal of 2045 is assessed. A reference building is examined by studying environmental product declarations (EPDs) for the CSC and aims to calculate its climate impact during the production stage in kg CO_2equivalent/m^3 (kg CO_2e/m^3) using the Environmental Building's calculation tool for indicator 15 (the climate impact of the skeleton). A comparison between EPD values and standard values for different concrete types is carried out to uncover their carbon dioxide footprint.

II. RESEARCH METHODOLOGY

A case study was conducted on a school in the city of Gävle in Sweden to calculate the climate impact of different types of concrete, and a survey was also performed in order to answer the study's questions. The study is thus a quantitative data analysis based on the selected methods. The following subsections address the evaluations of the compiled statistics in the survey and the data that the climate tool highlight.

A. Survey

The purpose of the survey was to compile the building and real estate sector's views of the CSC and how common they are in new production. How is work with the CSC ongoing? What are its pros and cons? These types of questions were expected to be answered by the survey.

First, a list of e-mail addresses from different companies was compiled using the Google search engine. A list of contacts was then created. Thereafter, an e-mail was made with a text that explained the purpose of the survey. The same e-mail was sent to everyone on the contact list. The sample group for this survey was intended for the building and real estate sector and was comprised of material producers, building contractors, constructors, architects, builders, clients, and/or process developers. The sample was a broad target group of small, medium, and large companies.

The initial stage of the design of the survey first consisted of a feasibility study on the CSC and traditional concrete. The survey that was chosen had the opportunity to collect data in a systematic way so that it could be repeated in the future. This was necessary to give the survey good reliability, i.e., the survey has the possibility to be conducted again, given the same circumstances.

A web-based survey was created via *'Webbenkäter'*, a website that creates surveys and applies analysis to questionnaires. The survey was designed to make it easier to reach out to occupations that work with concrete. The program had the possibility to design open and closed questions in a number of different forms and additionally to insert texts and pictures.

The survey was divided into different parts with a total of 19 questions. It began with a cover letter that outlined the purpose and background of the research work. Furthermore, this notified that the survey was anonymous and clarified that it included a broad target group. The purpose of the clarification was to point out that not all the questions may suit everyone, and they could, based on their occupations, answer what was related to them.

As a basic introduction to the survey, participants were asked to provide simple information about the company regarding the number of employees and the type of conducted activities. Subsequent questions were concerned with the type of concrete and cement they work with and what the possible additive materials are. The next questions were about the Sweden's climate goals of 2045, in which the participants' position on the goal was requested. In this part, there was the possibility of mentioning own opinions and evaluations based on a personal consideration, which means that the survey did not rely solely on facts.

The companies' use of the CSC was also taken into account in cases where they use the CSC or not. Finally, comments on the future of the cement industry were considered. Its purpose was to analyze what participants know about the possible work in the development of the CSC. Accordingly, there were open-ended questions that led to degrees of freedom for personal opinions in the participants' answers.

The step after the design of the survey was to send an e-mail to the selected target group, where e-mails were totally sent to 92 companies. The compilation of the questions with the closed answer alternatives took place with the help of Excel's diagram functions. These are presented in the form of figures and tables. In the questionnaire, the closed questions were supplemented with open-ended questions, which are analyzed in the discussions section.

B. Description of Reference Object

The case study was performed on a specific object in Gävle. The object is a school, Stigslundskolan, which has been constructed and managed by the Gävle real state that owns and manages real estate for municipal activities, and it is owned by the Gävle municipality. The facades of the building to the east and north are illustrated in Fig. 1.

The Environmental Building has a calculation tool that consists of formulas in an Excel sheet where it is possible to calculate the climate impact of building products in kg CO_2/kg, which is based on raw data available in EPDs. The products can be compared by the consideration of their EPDs if available, because they are developed on the basis of the same criteria. An EPD provides information about the product, method choices, and results of the environmental impact. To calculate the climate impact, knowing the amount (kg) of material used to complete the school was required.

The school was completed in 2017 and included three floors, of which only floor 1 has walls that consist of only concrete and insulation. Floor 2 has certain exterior walls made of concrete, wood, or a combination of these two as well as insulation. The Gävle real estate provided the information about concrete that they used to rebuild the school, as listed in Table 1. In the table, CEM designates cement.

C. Calculation of Climate Impact

Calculation of the climate impact is reported here. When comparing the climate impact of concrete used for the building, information was required on the type of concrete that the Gävle real estate utilized for the building and the EPD of the concrete type. The Gävle real estate mentioned that they used concrete from Betongindustri AB, which is a manufacturer and supplier in Gävle.

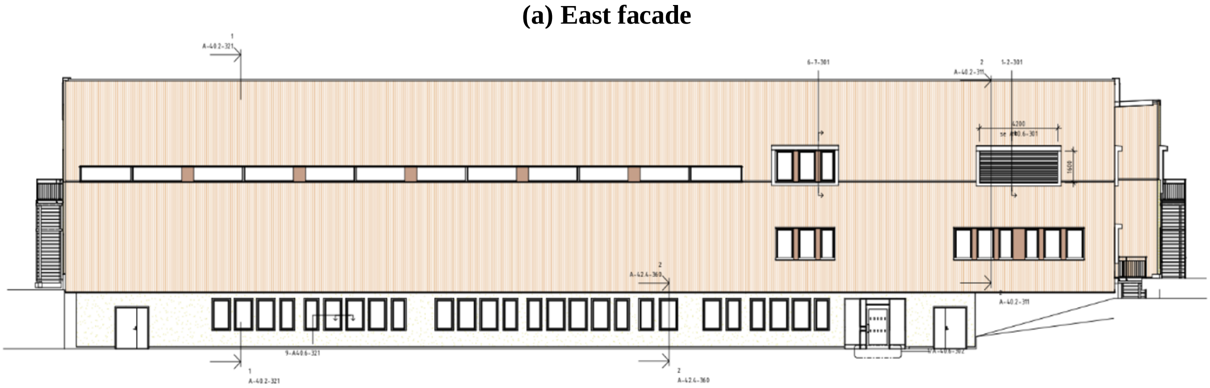
To find concrete with the same functional requirements, equivalent concrete with equivalent properties for exterior walls was searched. A comparison of different EPDs was then made. Consequently, reference concrete 1 was chosen, which is standard with a global warming potential (GWP) value of 345 kg CO_2/m^3. Reference concrete 2 was taken from Swerock with 98% Portland cement. These references were chosen to demonstrate differences in the carbon dioxide emissions. The concrete manufacturers for the three types of the CSC with different additive materials were Betongindustri AB, Swerock, and a member company in Svensk Betong. The last one had not been included in the manufacturer's company name by Svensk Betong. Properties of the selected concrete types and additive material as GGBS are summarized in Table 2.

The concrete volume of each exterior wall was calculated and summed for each floor. The concrete mass was inserted into the calculation tool. Fig. 2 displays details of four exterior walls. Fig. 3 presents the location of the exterior walls in the building. In Fig. 3, the solid lines correspond to the exterior concrete walls, while the dashed lines are exterior walls with wooden frames. The latter was not included in the calculation of the volume or in the calculation of the carbon dioxide emissions. In Figs. 2 and 3, EW stands for the exterior wall.

In the comparisons, total carbon dioxide emissions in the production stage (A1-A3) of concrete were taken into account, which includes raw material supply, transport, and manufacturing, respectively. Each EPD receives a GWP value for A1-A3. A summary of the calculated total CO_2 emissions from each type of concrete is provided in Table 3.

The generic data for each concrete type that were thereafter used in the calculation tool were obtained by dividing the GWP values by the density, as given in Table 4.

(a) East facade



(b) North facade

Fig. 1 Facades of building: (a) East facade, (b) North facade.

III. RESULTS AND DISCUSSIONS

The study has good reliability as it can be repeated. It also has high validity since it is based on public documents, books, and building companies with different practical experiences of concrete. Concrete production is constantly evolving, and new improvements come to the knowledge, which means that repetition of the study will have a different effect. Thus, the reliability can be affected by new conditions. To counteract this, we present the used data and also when different values have been utilized.

A. *Survey*

The results of the survey received a number of external and internal cancelations, as well as personal evaluations and competencies. As it was mentioned, the questionnaire included closed and open questions. The closed questions gave quantitative results, which are reported in the form of figures. The open-ended questions are further analyzed in the discussions.

Table 1. Functional conditions for building to choose suitable concrete and EPD.

Features	Interior concrete structures	Interior walls	Exterior concrete structures
Exposure class	XC1	XC1	XC4 + XF3
Working life class	4 (50 years)	4 (50 years)	4 (50 years)
Concrete quality	C50/60	C25/30	C30/37
Maximum water-to-cement ratio	0.4	0.9	0.5
Frost-resistant ballast	-	-	Yes
Air content	-	-	4.5%
D_{max}	-	-	16 mm
Cement type	CEM II	CEM II	CEM II

Table 2. Comparative properties and additive material for each concrete type.

Concrete type	Strength class	Exposure class	Cement	Proportion of cement (%)	GGBS (%)
Reference concrete 2	C30/37	XC4 + XF1	Cementa Velox	13	2.8
Betongindustri	C30/37	XC4 + XF1	Additive Material Type II	14	1.19
Swerock	C30/37	XC4 + XF1	Cementa Byggcement	13.5	0
Svensk Betong	C30/37	XC4 + XF1	Cementa Bascement	14.4	0

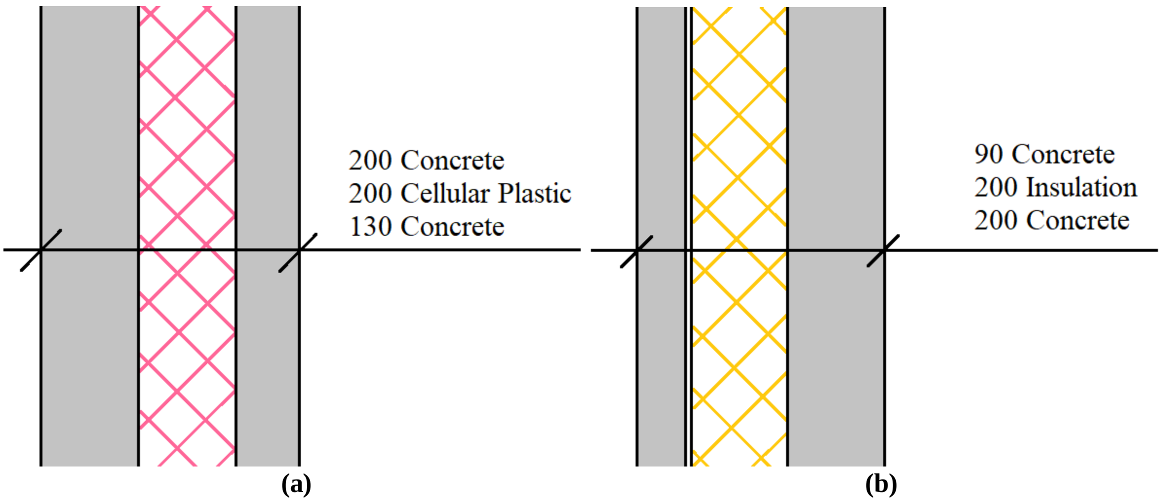


Fig. 2 Details of exterior walls: (a) EW1, (b) EW2, (c) EW3, (d) EW4, (Unit: mm).

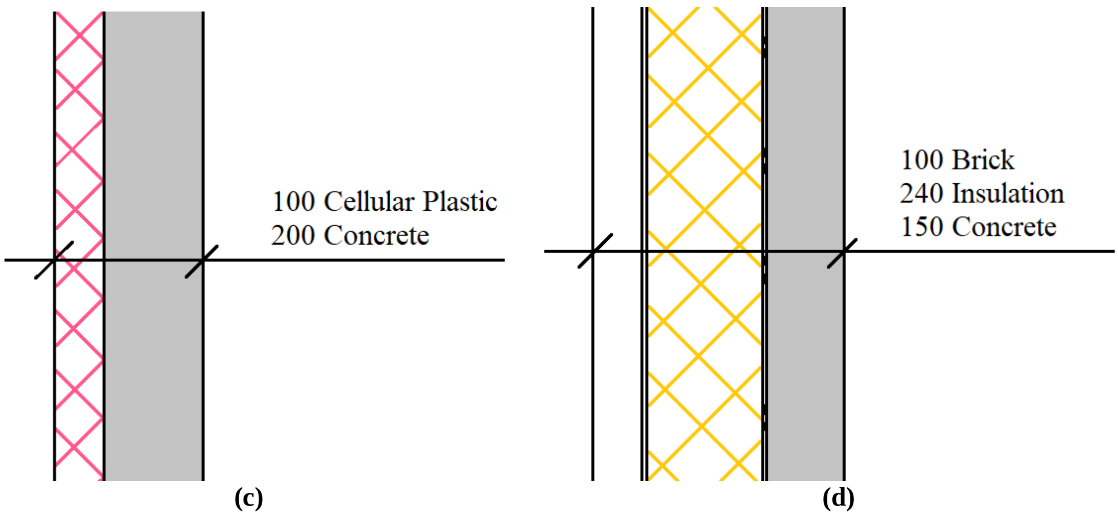


Fig. 2 Continued.

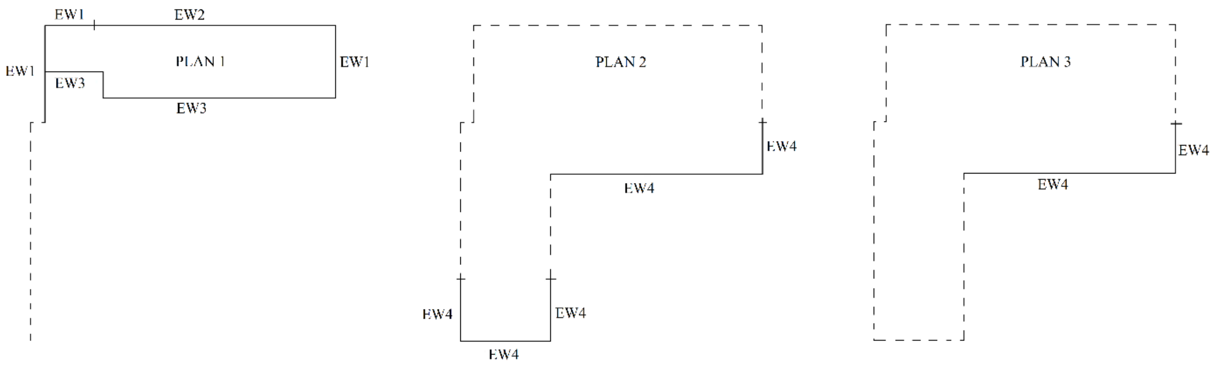


Fig. 3 Location of exterior walls in building.

Table 3. Climate impact of each concrete in production stage and its total GWP value for each EPD.

Concrete type	A1 Raw material supply	A2 Transport	A3 Manufacturing	Total GWP	Unit
Reference concrete 2	239	7.51	3.64	251	kg CO_2e
Betongindustri	236	6.98	3.31	247	kg CO_2e
Swerock	234	7.27	5.05	246	kg CO_2e
Svensk Betong	237	6.02	1.00	244	kg CO_2e

Out of 92 respondents, 26 companies participated, of which 14 completed the entire survey. The proportion of employees at various companies that participated in the survey is shown in Fig. 4. As stated earlier, the survey revealed external and internal cancelations. That is why the frequency of responses to certain questions and the number of respondents' participation differed. The feedback received from various cancelations was that they did not consider themselves a relevant participant. The evaluation of the questionnaire was compiled in Excel and visualized in figures. The results of the survey are presented based on 14 participants' responses. Some questions could be responded to with more than one response option.

Figs. 5-16 provide the results achieved from the closed questions. In Fig. 5, one participant was an element manufacturer, and another one was a house supplier that were taken as *'Other'*. In Fig. 6, one participant responded as grouting and stabilization, and another one mentioned that it is up to the client to determine the foundation type; these were considered as *'Other'*.

Table 4. Compilation of final generic data for calculation tool.

Concrete type	GWP (kg CO_2/m^3)	Density (kg/m^3)	Generic data (kg CO_2/kg)
Reference concrete 1	345	2300	0.1500
Reference concrete 2	251	2353	0.1067
Betongindustri	247	2358	0.1047
Swerock	246	2353	0.1045
Svensk Betong	244	2360	0.1034

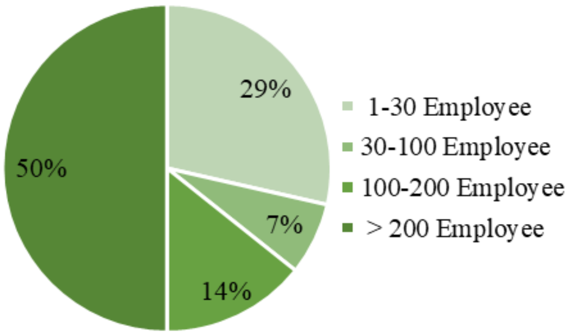


Fig. 4 Proportion of employees at various companies that participated in survey (Number of participants: 14).

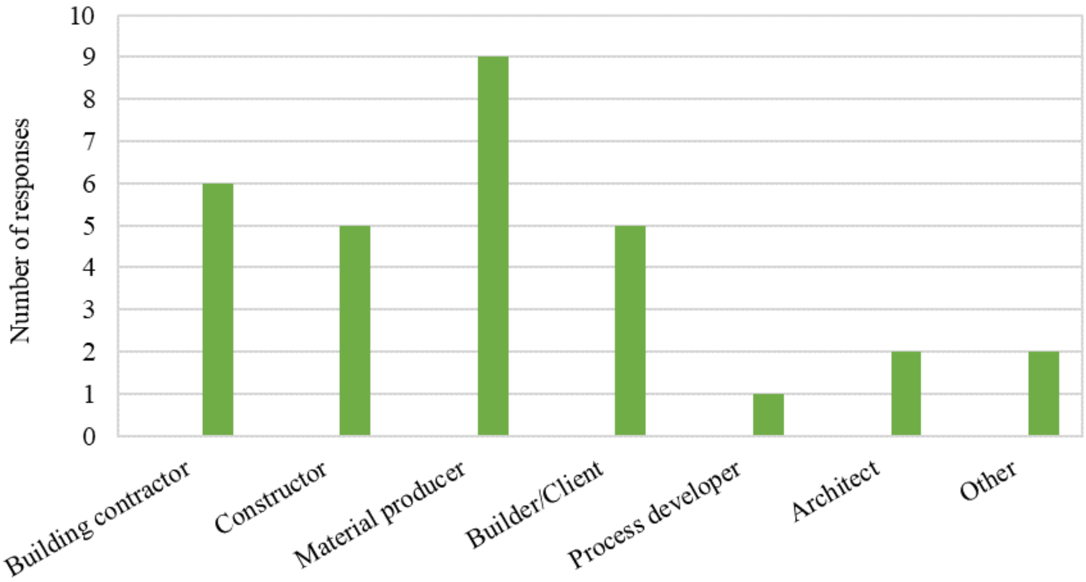


Fig. 5 Types of activities that companies perform (Number of participants: 14).

The results of Fig. 7 indicate that the most common type of cement was CEM I, which consists of Portland cement, while CEM II was the second most common. CEM IV and CEM V were not demonstrated to be common in Sweden. The second most common type of cement, CEM II, with its associated additive materials, is represented in Fig. 8. The word *'Other'* in Fig. 8 implies that one participant did not know it and another one used GGBS. Fly ash and limestone were the most common additive materials employed among the eight participants of this question. Fig. 9 depicts participants' attitudes towards achieving the Sweden's net-zero goal in which concrete should be climate neutral by 2045. Out of 14 participants in the survey, they mostly responded with a positive attitude.

The subsequent questions gave the participants the possibility to reflect on how they work to achieve the Sweden's climate goal or what they see as an obstacle to accomplishing the goal by 2045. Fig. 10 reveals the knowledge of the participants regarding various types of the CSC available in the market. According to the figure, most of the participants were well aware of them and were working to integrate them into their activities.

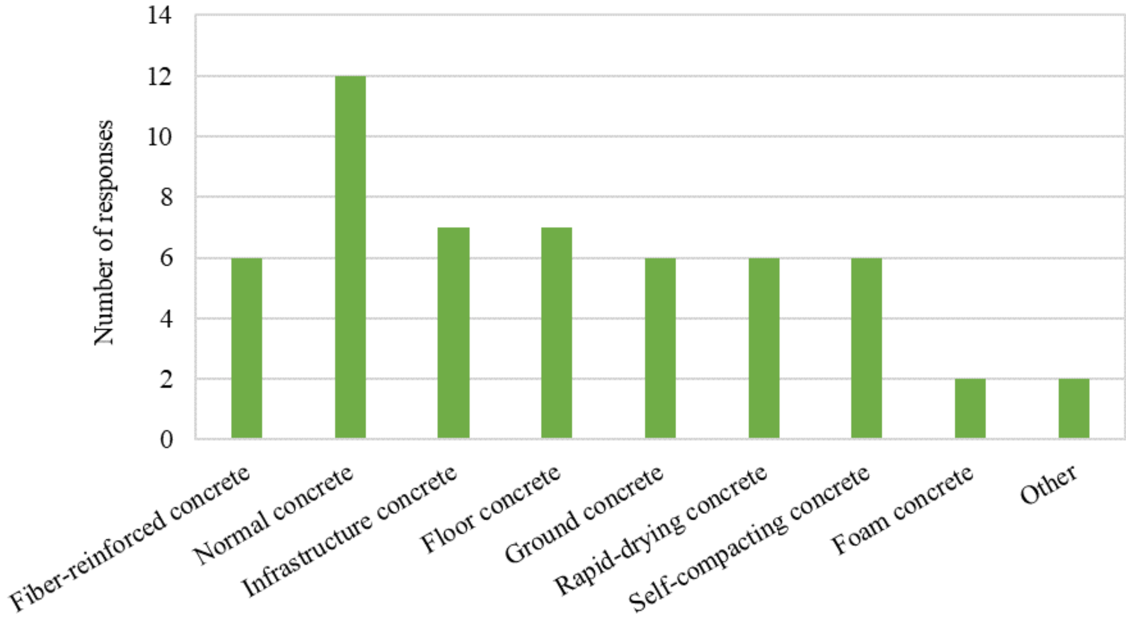


Fig. 6 Types of concrete that companies currently work with (Number of participants: 14).

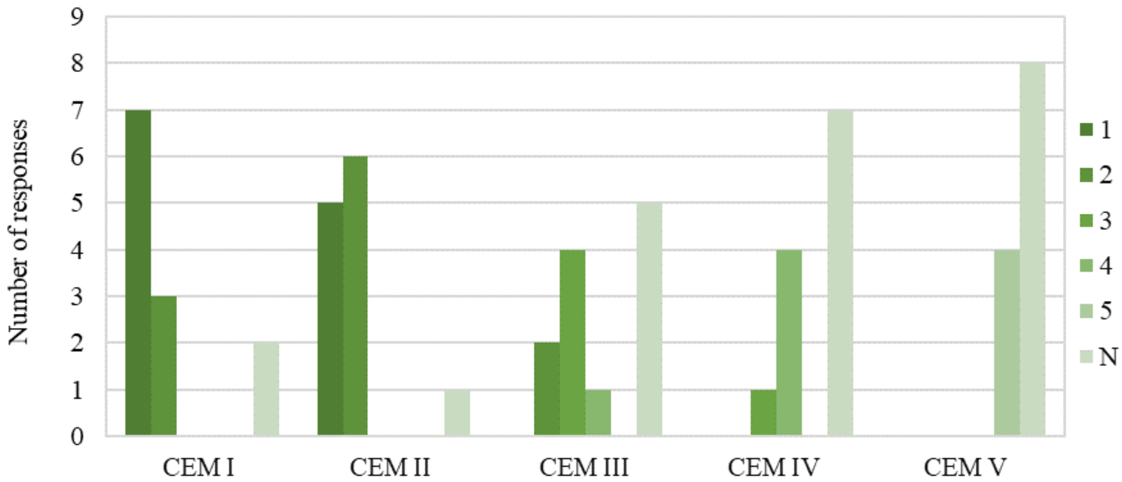


Fig. 7 Types of cement that companies usually work with: 1 corresponds to the most common type, and N means company does not work with (Number of participants: 14).

Fig. 11 elaborates the participants who had an idea to switch to a climate-smarter concrete than those used by them. One reason why some companies did not choose to switch to it may be because the building industry feels so comfortable working with concrete having the Portland cement clinker. Consequences of not being willing to explore other alternatives mean that the new modern CSC available today does not easily enter the market. This can then arise for a number of reasons that do not necessarily have to be true, such as costs. There is an unfounded perception that climate-smart products are usually more expensive but are something that can be seen as favorable in the long run. On the other hand, sustainability is the issue that is advocated by the public today.

Fig. 12 clarifies why various companies do not employ the CSC based on different reasons highlighted in the figure. The participants' insecurity prior to working with the CSC can be found in the figure too. This issue can be partly due to the different personal competencies of the participants and partly owing to the informative notifications from various concrete manufacturers. In addition, it can be deduced from the figure that seven participants considered the cost to be an obstacle today.

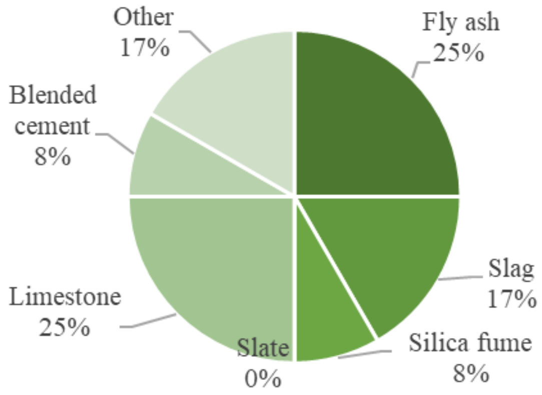


Fig. 8 Types of additive materials utilized by those who use CEM II (Number of participants: 8).

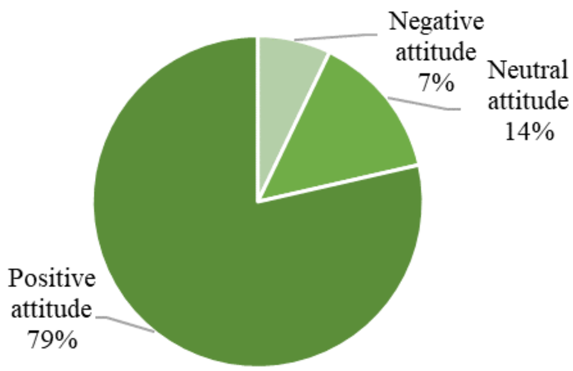


Fig. 9 Attitudes towards achieving Sweden's net-zero goal by 2045 (Number of participants: 14).

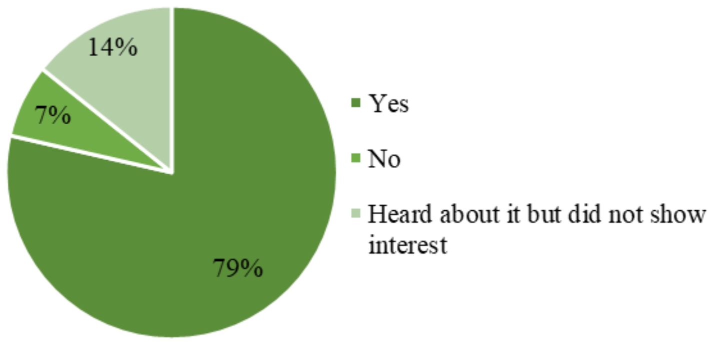


Fig. 10 Knowing various types of CSC in concrete industry (Number of participants: 14).

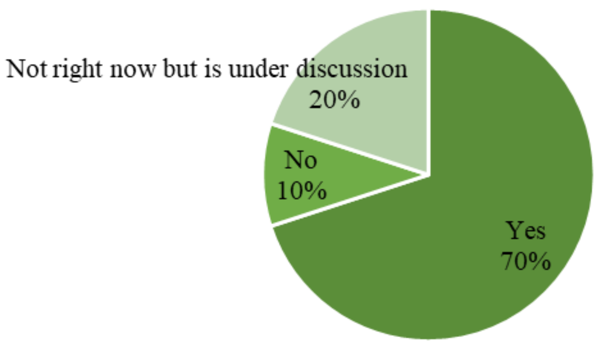


Fig. 11 Having an idea to switch to a climate-smarter concrete than those used by participants (Number of participants: 10).

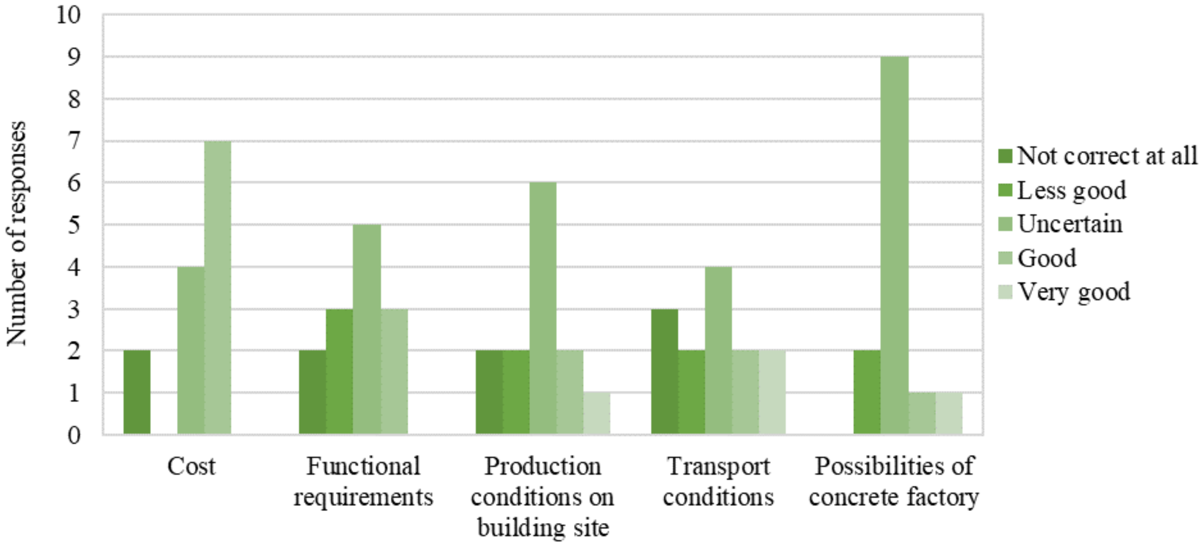


Fig. 12 Types of challenges that those participants who do not work with CSC expect to have before working with it (Number of participants: 13).

Fig. 13 illustrates types of the CSC that are usually used by those participants who currently work with them. The most common additive materials utilized by the participants were limestone and fly ash (Fig. 8) which can be linked to Fig. 13, where most of the participants answered that they use Cementa Bascement in their concrete. Skanska applies it in its Grön Betong as well. Cementa Bascement has additive material, which, among other things, is fly ash. Additionally, Cementa has produced Byggcement with limestone, which is also one of the most common additive materials among the participants. It can be concluded that Cementa's different types of cement are at the forefront of various self-developed concrete types that exist in the industry today. It is worth mentioning that Cementa is progressively withdrawing from fly ash as an additive material by continuing the development of limestone and slag as additive. Cementa is developing its CSC and is working to reduce the carbon dioxide emissions and to utilize slag. The advantage of concrete with Portland fly ash cement is the reduction of the carbon dioxide emissions by using fly ash, which is a slag product from coal power plants. However, this is also a disadvantage as there is a decommissioning of coal power plants in Sweden. This means that fly ash will not be an alternative as an additive material in the future.

Fig. 14 depicts how those who currently work with the CSC consider it to be good or bad. The figure uncovers that the cost does not really have a significant impact when working with the CSC, which contradicts the views of those who responded in Fig. 12, in which it was considered as a challenge.

Fig. 15 shows the participants' awareness of future short supply for concrete with fly ash. Fig. 16 indicates if the participants are aware of the cement industry's work to counteract the carbon dioxide emissions or not. The majority of the participants considered themselves to be up to date on the future development of the cement industry, as stated in Figs. 15 and 16. However, there were a number of participants who were not aware of various works carried out to minimize the carbon dioxide emissions of the cement industry.

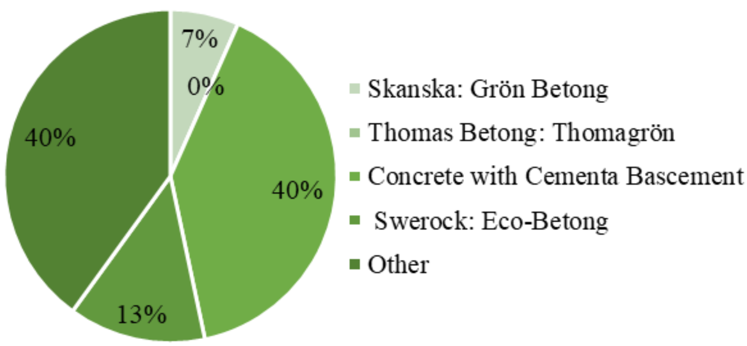


Fig. 13 Types of CSC used by participants (Number of participants: 11).

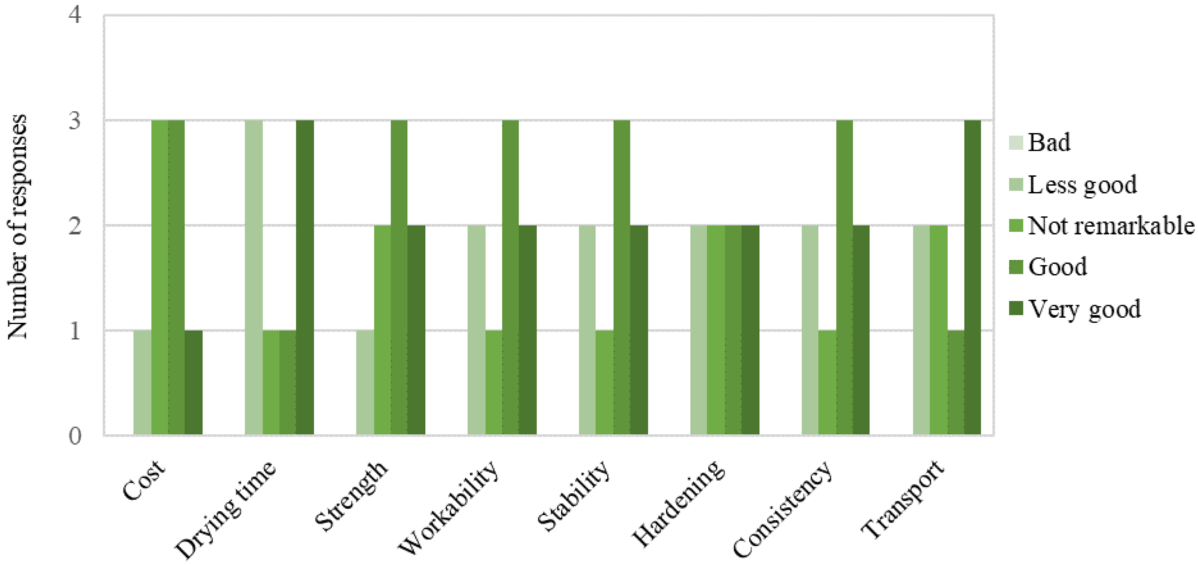


Fig. 14 Attitudes of participants who currently work with CSC based on various aspects (Number of participants: 8).

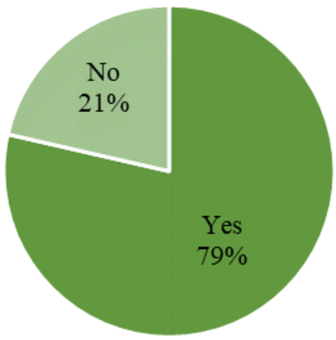


Fig. 15 Awareness of future short supply for concrete with fly ash (Number of participants: 14).

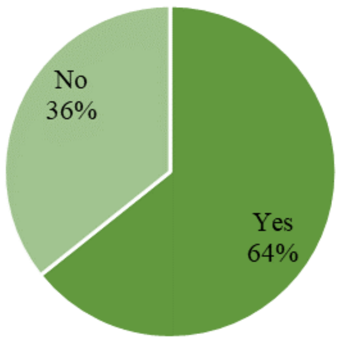


Fig. 16 Knowing Norway's goal to store carbon dioxide in bedrock that is emitted during production of cement (Number of participants: 14).

The results of the open-ended questions were qualitative and contained participants' thoughts and evaluations. These questions were needed for this study as we wanted to know how different companies' positions and assessments for the CSC were. The external cancelations in the survey were mainly due to the participants who were considered relevant by the authors, perceiving their own activities as irrelevant.

Regarding what participants took into account as obstacles with the carbon dioxide emissions from concrete being net-zero by 2045, most of them did not see an obstacle. However, the obstacle was considered to be a political responsibility, and also, some companies were not ready for this new development. The building industry is known for having an old way of thinking, and the new goals require the industry to rethink and introduce a new way of thinking about the CSC. Another opinion was the designers' high demands in relation to the lack of time in projects that should be taken into consideration in the change that the sustainable society asks for.

Moreover, the participants were asked how they view the work process when switching to the CSC. The participants described that the industry has an outdated way of thinking by thinking of "concrete as concrete". The question was met with the answer that greater thought is required in the design process. It requires time and resources to compare different materials and use the CSC for a final sustainable result. It was pointed out that the CSC does not exist today, by reasoning that as long as the material contains cement regardless of the admixture of additive materials. The critical answers from the participants may be due to the fact that fly ash comes from coal power plants which is a major environmental problem and is also being phased out in Sweden. The concrete industry needs more alternative solutions for the future.

In order to be able to make a change to the CSC, the participants discussed that it is necessary for builders to be informed and guided to invest in environmentally smart alternatives. It requires greater knowledge and responsibility on the part of companies to be able to assist clients with the right information. Requirements from authorities are slow but surely getting more into the industry. A cleaner as well as cheaper energy, investment support for smaller companies, and a political system that evaluates concrete, steel, and wood equally were commented to achieve a sustainable society for future generations. Based on the survey, it was perceived that the CSC works relatively well in various aspects that are addressed. What can further be discussed is whether acceptable trade-offs have been found between cost and performance.

Regarding the continuation of the future development of the cement industry, there were some opinions mentioning that the future looks bright for concrete and there will be a future that includes concrete, as long as the development of environmentally smart solutions continues. There were also fewer positive opinions believing that it first and foremost requires updating and using modern concrete, which meets today's requirements and gives more space to innovative products so that the smart development can continue.

B. Comparison of Carbon Dioxide Emissions of Different Types of Concrete

The results achieved from the calculation of the total volume and weight of concrete used in the building are given in Table 5. The results obtained from the Environmental Building's calculation tool are presented in Table 6. In this table, the generic data and total weight were adopted from Tables 4 and 5, respectively.

The results accomplished from the comparison of the reference concrete 1 with the standard value and the three selected types of the CSC are displayed in Fig. 17. The reference concrete 1 gave a result with the largest reduction of carbon dioxide for 29.3%. These types of concrete that were compared had different additive materials, which affected the final results. It can be observed that the CSC with additive material had a lower climate impact in the production stage (A1-A3) in comparison with the reference concrete 1. Also, the member company in Svensk Betong had the lowest climate impact, unlike the other types. This company uses Cementa Bascement, whose additive material is fly ash with a content of 14.4%. Comparing Betongindustri's concrete with that of Swerock, a slight difference is witnessed. However, Fig. 18 indicates the total climate impact in CO_2 (kg) for each CSC in comparison with the reference concrete 2 which uncovered a maximum reduction of carbon dioxide for 2.8%.

Table 5. Volume and weight of concrete.

Exterior wall	Volume (m^3)	Weight (kg)
Plan 1	130.418	306482
Plan 2	19.838	46619
Plans 2 and 3	44.237	103957
Total	194.5	457058

Table 6. Final climate impact of each concrete in production stage.

Concrete type	Generic data (kg CO_2/kg)	Total weight (kg)	Total CO_2 (kg)
Reference concrete 1	0.1500	457058	68559
Reference concrete 2	0.1067	457058	48768
Betongindustri	0.1047	457058	47854
Swerock	0.1045	457058	47763
Svensk Betong	0.1034	457058	47260

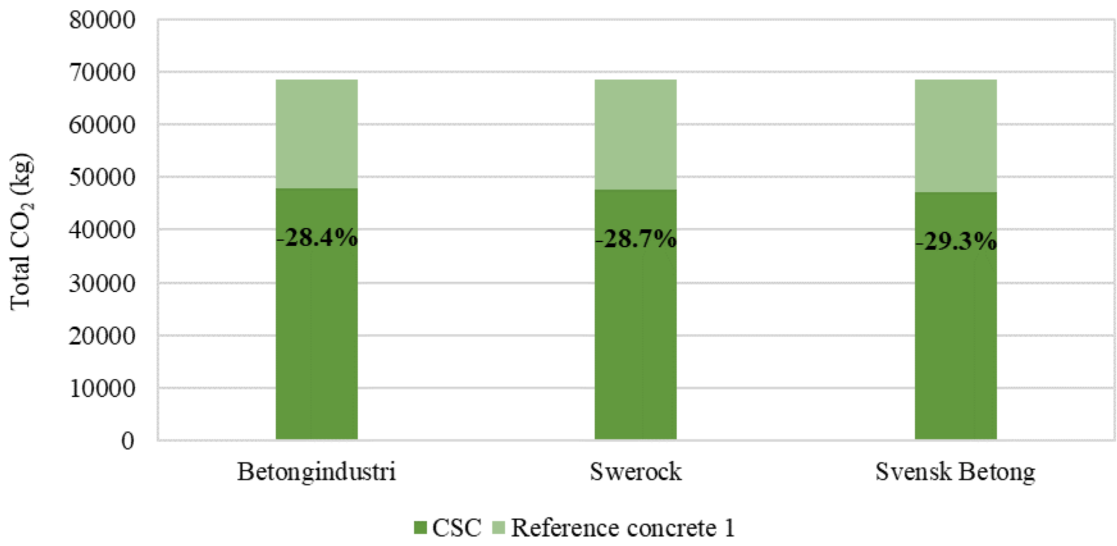


Fig. 17 Climate impact of different types of concrete in comparison with reference concrete 1.

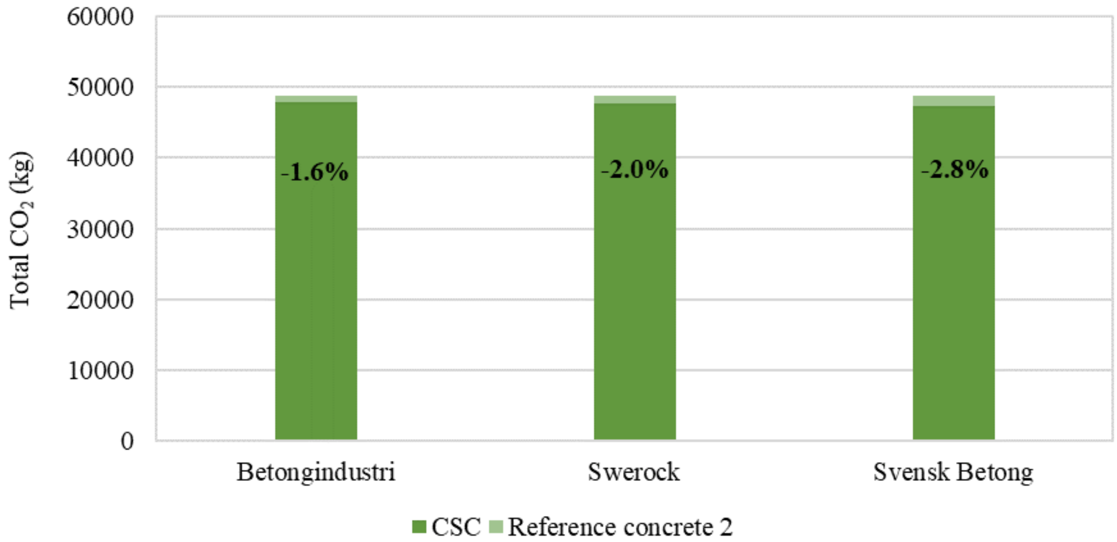


Fig. 18 Climate impact of different types of concrete in comparison with reference concrete 2.

IV. CONCLUSIONS

The study demonstrated that Portland cement is still used by several building companies that build with concrete, despite the existence of several climate-smart alternatives. As the availability, cost, and drying time were factors that the participants agreed on if not an obstacle, it seemed that there was uncertainty. This uncertainty could be due to less knowledge about the CSC regarding the social, economic, and sustainable aspects. Assessment of GWP values gave an indication of which concrete would be a better climate-smart alternative. It can also be stated that the market is not mature for the concept of the CSC yet, based on the minimal difference between the carbon dioxide footprint for each CSC for exterior walls with strength class 30/37 and exposure classes of XC4 and XF1. If the types of the CSC are compared with a standard value, a considerable difference in the carbon dioxide footprint is seen, and thus the concept of climate-smart can be applied. This is an indication of an immature market that does not compare the CSC in a fairway. The current immature market of the CSC requires more research on a sustainable alternative that replaces cement, in larger quantities or completely, in concrete. Despite successful additive materials that have been produced, there is still some uncertainty about the properties of concrete and how the building and real estate sector should plan its projects based on its properties. It is required that building companies consider more time and planning to apply the right concrete in the right place. In cases where the CSC is not available for all types of constructions, it is possible to combine and at least have inner walls or skeletons in the CSC so that everyone can contribute to it.

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