Impact of lower CO_2 emission cement on TT-slabs fast production

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Subject Impact Of Lower CO_2 Emission Cement On TT-slabs Fast Production
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Cement production is responsible for 7% of global carbon dioxide emissions. Because of this huge percentage, the concrete industry is one of the biggest industries, making the world less livable. It is important to reduce emissions because there is not yet anything completely replaceable for cement and concrete.

This thesis aims to make a concept recipe for TT-slabs using lower CO_2 emission cement in the market. In particular, the TT-slabs topic has been chosen as a research topic because the commissioning company Suomen Kovabetoni Oy has an existing recipe of less CO_2 emission cement for elements such as beams and columns, by which the company has achieved good results considering the reduction of CO_2 emission.

Many factories can make less emission concrete elements but to optimise the resource, time plays an important role. Another aim of the thesis is to achieve a recipe where production and material costs do not increase.

As a prefabricated element, TT-slabs are thin elements. Getting 60% of the final strength of the used concrete class is very important in terms of safety and resources and that also plays a critical role in maintaining the strict mass production timetable.

Finding out the solutions to this matter is the target of this thesis by testing different mixing ratios of CEM-3 and RAPID cement at different times.

Keywords Cement, concrete, pre-tension, TT-slabs, CO_2 emissions, low-carbon
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Tutkintonimike: Insinööri (AMK), Rakennustekniikka Tiivistelma

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Aihe Vähemmän CO_2-päästöisen sementin vaikutus TT-laattojen nopeaan tuotantoon.

Ohjaaja(t): Ahmad Shahgordi(HAMK), Mikko Saarela(Suomen Kovabetoni Oy)

Sementin valmistusprosessi on vastuussa 7 prosentista maailmanlaajuisista hiilidioksidipäästöistä. Tämän valtavan prosenttiosuuden vuoksi betoniteollisuus on yksi suurimmista teollisuudenaloista, joka tekee maailmasta vähemmän elinkelpoisen. Koska meillä ei vielä ole mitään täysin korvaavaa sementille ja betonille, yritämme jatkuvasti vähentää päästöjä.

Tämän opinnäytetyön tavoitteena on tehdä konsepti vähä paastoiselle TT-laatoille käyttämällä markkinoilla olevia vähemmän CO_2-päästöjä tuottavia sementtejä. Erityisesti TT-laatat aihe on valittu tutkimusaiheeksi, koska toimeksiantaja Suomen Kovabetoni Oy:llä on olemassa resepti muihin runkotuotteisiin, kuten palkkiin ja pilariin, joissa yhtiö saavutti hyviä tuloksia CO_2-päästöjen vähentämisessä.

Moni tehdas pystyy valmistamaan vähempi päästöisiä betonielementtejä, mutta resurssien optimointi on tärkeässä roolissa. Toinen tavoite on luoda resepti, jossa tuotanto- ja materiaalikustannukset eivät nouse.

Valmis-elementtinä TT-laatat ovat ohuita elementtejä. Käytetyn betoniluokan 60 % loppulujuudesta saaminen on turvallisuuden ja resurssien kannalta erittäin tärkeää ja sillä on ratkaiseva rooli tiukan tuotantoaikataulun ylläpitämisessä.

Tämän opinnäytetyön tavoitteena on löytää ratkaisut tähän asiaan testaamalla erilaisia CEM-3:n ja RAPID-sementin sekoitussuhteita eri aikajaksoissa.

Avainsanat Sementti, Betoni, Esijännitys, TT-laatat, CO_2 päästöt, vähähiilinen.
Sivut 31 sivua, liitteiden lukumäärä 3 sivua.

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Special vocabulary

CO_2	Carbon dioxide
Hydration	Chemical reaction and bonding process of water and cement
GWP	Global Warming Potential
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
Green concrete	Low-carbon emission concrete

1 Introduction

Today people are more conscious about the climate and how we can keep the climate clean for good living conditions. For that reason, countries are bringing new regulations to keep the climate clean and prevent more pollution.

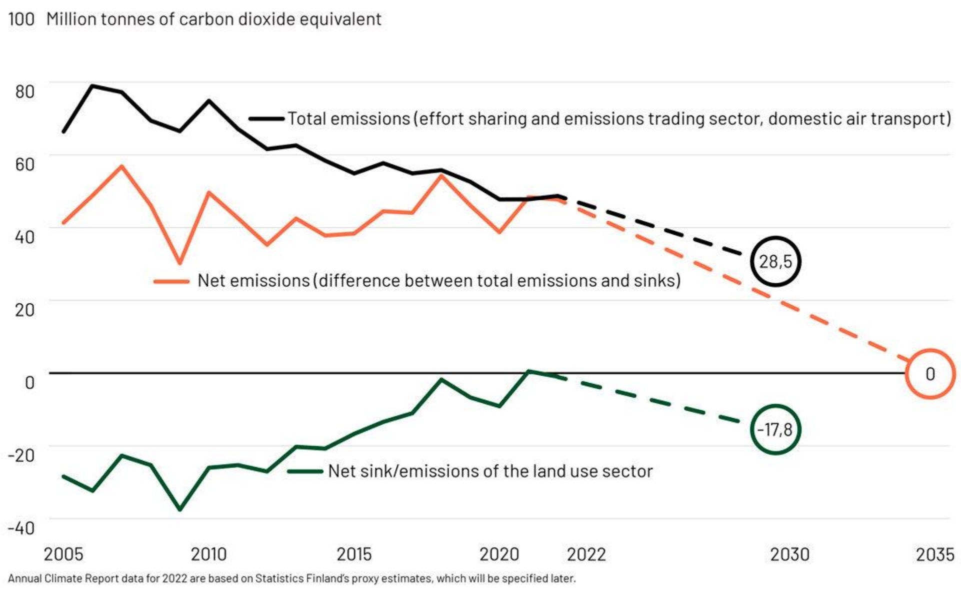
In the year 2022, human activities generate almost 54 billion tons of greenhouse gas. Most of this pollution happens due to CO_2 emissions. CO_2 is responsible for 72% of these emissions, then comes methane, nitrous oxide and other greenhouse gases. At the European level these 27 countries together responsible for 6,7% of this GHG and 7,3% of CO_2 emission. That is why most focus is now on CO_2 and how can we reduce its emissions. (European Commission, n.d)

When we divide the industries, that play a vital role in this pollution, the Construction industry finds its position in the top ten of the list. European Union is playing an important role in reducing these emissions. On the EU level, the target is to be carbon neutral by 2050 but Finland is walking on the path to reducing CO_2 emission by 40 per cent by 2030, then carbon neutral by 2035 and carbon negative by 2050. To achieve this, all industries that generate a lot of CO_2 should focus on greener options to reduce emissions. (Valtioneuvosto, 2022)

According to the Finnish Climate Change Panel, there is a significant gap between Finland's current actions and the target. Specifically, these actions account for only about 16 megatons (Mt) of the emission reductions of 35 Mt that will be needed. This means there is a gap of about 19 Mt between the target and actions. This estimate takes account of both actions decided earlier and measures included in the Energy and Climate Strategy and the Medium-Term Climate Change Policy Plan (KAISU). The Finnish Climate Change Panel estimates the size of the carbon sink to be 21.4 Mt. Different stakeholders have also outlined different kinds of paths toward carbon neutrality. (Valtioneuvosto, 2022)

Similarly, in the Ministry of Economic Affairs and Employment's PITKO follow-up study on the long-term trend in total emissions, the need for reductions in the continuous growth scenario was estimated at 34 Mt (both sink and emissions 23 Mt) or in the savings scenario at 43Mt (both sink and emissions 12 Mt). Which is shown in figure 1.

Figure 1. Target of carbon neutral era. (Valtioneuvosto n.d.)



According to the Finnish Climate Change Act, Finland's net emissions will be zero or negative by 2035. By 2030, emissions must be reduced by 60%, using 1990 as the baseline. It has been agreed at the EU level that the carbon sink of Finland's land use sector must amount to -17.8 million tonnes of CO_2-eq in 2030.(Valtioneuvosto, 2023)

Part of achieving the climate-improving goal of Finnish construction is moving towards a carbon-neutral era. Cement manufacturing causes the most carbon dioxide emissions in the construction sector. Due to this, new low-carbon cements have entered the market. Also, construction is going forward at its own pace.

2 Introducing the client company

Suomen Kovabetoni Oy is a Finnish family-owned company of precast elements. Their first precast element company was established in Turku in 1994. Turku also serves as the company headquarters. As the company was not built so long ago, almost all modern technology and machinery are used to fabricate precast elements there.

In 2019 Kovabetoni bought the precast element factory in Nastola, Lahti. This new element factory focuses on fabricating hollow core slabs, TT slabs, columns, and beams, and the Turku factory focuses on solid wall elements.

Kovabetoni, before establishing their precast element factory had been in the construction business since 1966, with their sister concern Rakennusosakeyhtiö Mäkinen. A good basic understanding of construction comes from over 50 years of experience in the construction sector.

2.1 Objective and scope of the study

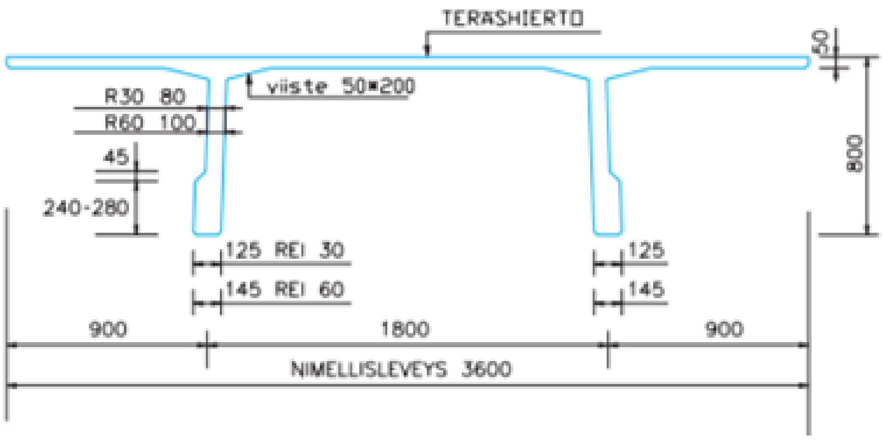
This topic is focused especially on the prefabricated element industry. One of the most produced elements is TT-slabs and lightened TT-slabs.

TT-slabs are prestressed reinforced concrete elements that are for long spans. TT slabs are mainly used in commercial and industrial construction, where a lot of space in the interior is needed. TT slabs are most often on the upper floor of the structure. The slopes of the water roof are made using equal-height height slabs together with HI beams. The maximum height of Kovabetoni's TT-slabs is 500 mm, and the maximum width is 3600 mm. (Kovabetoni n.d.). These slabs are shown in figure 2.

Figure 2. TT-slab from Kovabetoni's Nastola Plant.

The lightened TT-slab is similar to TT-slabs but lighter in weight. Because of its more cost-effective and effective load-bearing capacity, lightened TT slabs can have even longer spans than TT slabs. Lightened TT-slab is mostly used in water roofs, but it is also suitable, for example, for intermediate floors in office buildings. The standard height of the lightened TT slab is 800 mm. The maximum width of the lightened TT slab is 3,600 mm. These dimensions are shown in figure 3.

Figure 3. Cross-sectional pictures of lightened TT-slab. (Elementtisuunnittelu n.d.)



As both TT-slabs are thin and long, and strengthened by pre-tensioned strands, it is important to have a balanced recipe that will give enough initial strength by 12 to 18 hours to lift from the casting bed and store in storage to get fully cured.

This study aims to determine the quickest initial strength of green concrete that can be achieved for the quick and efficient manufacture of TT-slabs. In the research phase, after the concrete hardened, the drying process was monitored with remotely readable sensors and strengths were tested in own laboratory. Finnsement's Rapid and Triple-cement will be used in this research. Tripple cement is the less CO_2 emission cement, where blast furnace slag has been utilized as a replacement ingredient to reduce the emission of cement CO_2.

Concrete classes used in manufacturing the elements are taken from the technical instruction of specific projects and elements according to EN-206 and SFS 7022. Usually concrete classes are between C35/45 to C70/85.

Steel materials and rebar are used according to the project's technical requirements. Standard SFS 1215, SFS 1257, SFS 1259, and SFS 1268 are used according to guidelines. The general strengths of used rebars and steel are between 500MPa and 600MPa.

This thesis is commissioned by Suomen Kovabetoni Oy, based on their current products and projects they have a balanced recipe for elements like beams and columns where the company achieved a reduction in CO_2 emissions by more than one-third compared to their old recipe.

Now the company intends to develop a reduced CO_2 emission recipe for TT-slabs. Where the company intends to show that using low-carbon building materials and techniques has the potential to lower CO_2 emissions in the construction industry by not increasing the price of elements.

3 Methodology

As the company, Suomen Kovabetoni Oy already succeeded in lowering CO_2 emissions for thicker elements, the company intend to have ready data for thinner elements too. Based on the current ongoing production recipe of concrete and concrete elements, in this thesis, the goal is to improve it by researching and testing different mixing ratios to have a better outcome with reduced emission of CO_2 for thinner elements.

3.1 Research Strategy

To proceed with the research and testing, seven different mixtures were made of different ratios of CEM3 and RAPID cement from Finnsementti to do our research. Our mixing ratios are

- CEM3 00% + RAPID 100%
- CEM3 30% + RAPID 70%
- CEM3 40% + RAPID 60%
- CEM3 50% + RAPID 50%

- CEM3 60% + RAPID 40%
- CEM3 70% + RAPID 30%
- CEM3 100% + RAPID 00%

Eight cubes for each recipe were made to have enough samples to do the testing. We needed five cubes for our test and the rest are extra.

3.2 Data Collection

Based on our target, we tested our mixture cubes five different times

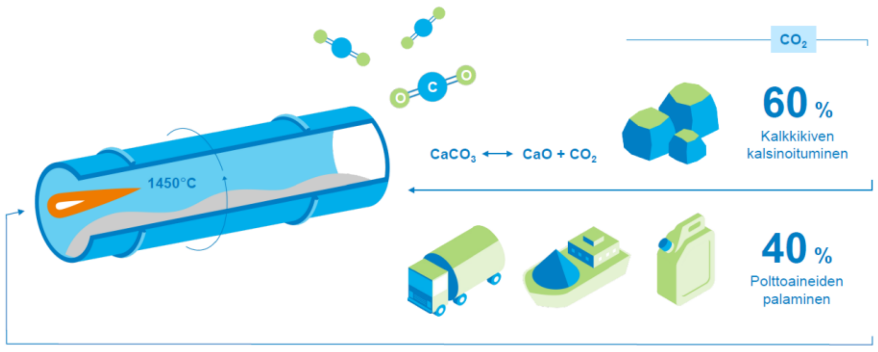
- 12 H
- 18 H
- 1 DAY
- 7 DAY
- 28DAY

Kovabetoni has their research laboratory in their Nastola plant, where all the tests were done and all these data are obtained from the test results. All the test results are in MPA. As weather and temperature play important roles in outcomes, we controlled the temperature in our laboratory in a way that is similar to our production hall temperature in the wintertime.

4 Concrete and Cements background information

Concrete is the most used construction material, it also emits a considerable amount of greenhouse gases. To make concrete, a strong binder is needed, which is called cement. Cement is responsible for 7% of the world's CO_2 emissions (Heikkilä, 2022). In figure 4, emissions are shown in percentages

Figure 4. CO_2 emission stages with percentage. (Finnsementti n.d.)



Almost one-third of total greenhouse emissions is happening because of direct construction and construction-related materials. For that reason, governments and companies are heading to a more carbon-neutral era. As governments are tightening the regulations and imposing new guidelines related to emissions strictly, companies are more focused and involved in finding different usable solutions.

Concrete is mostly used construction material and in concrete cement is used as a binding element. Alone the strength of cement is very weak. To get strength like stones, cement needs to be combined with sand and gravel. Cement comes from limestone. The mixture is heated to 1400°C traditionally by gas or coal to release the CO_2 from limestone. Cement production brings 7-8 % of the world's CO_2 emission. (Betoni n.d).

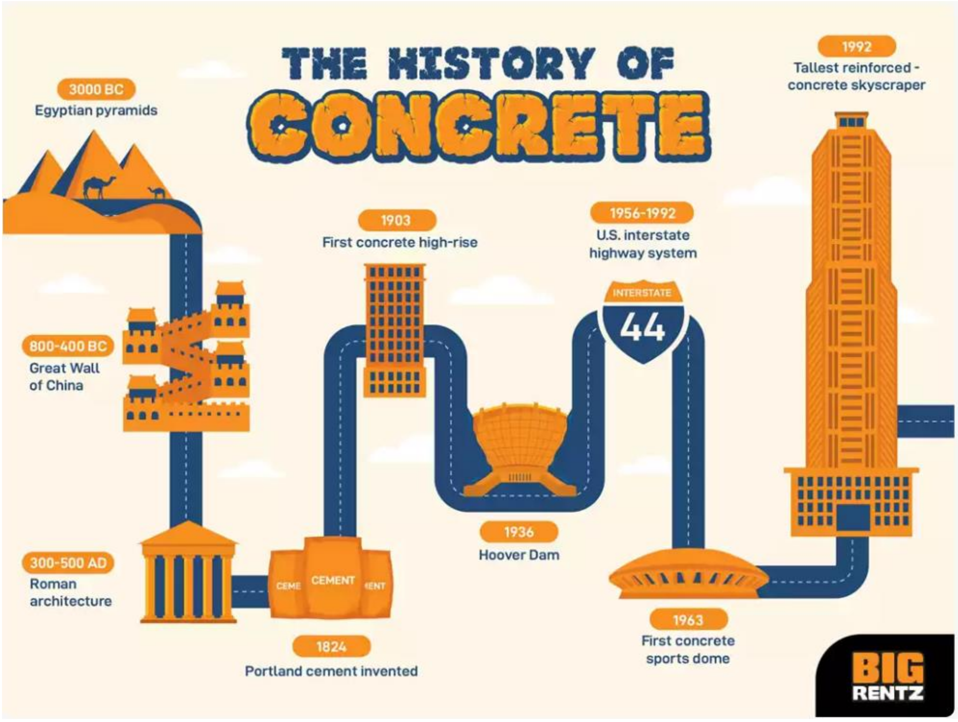
For greener or green cement, a portion of limestone is replaced by fly ash or blast furnace slug as a binding element. This way emission is reduced by 90%. It also reacts slowly compared to traditional Portland cement. (Betoni n.d).

4.1 Concrete

Concrete has been in existence for us to be used in various forms to be found. The very initial evidence of concrete was found in Israel. It was a floor from a hut, dated back to 7000BC. Burning limestone was then used to make quicklime and mixed with water and stone to set and harden.

This knowledge of lime-based material travelled fast to Egypt and Ancient Greece and reached the Romans around 300 BC. The word "concretus" comes from Latin, In English, it is explained as *"A hard strong building material made by mixing a cementing material (such as Portland cement) and a mineral aggregate (such as sand and gravel) with sufficient water to cause the cement to set and bind the entire mass." (*Merriam-Webster n.d). The Romans discovered a volcanic material that had cementing properties, known as Pozzolanic cement. Examples of concrete made with this cement still exist in structures such as the Pantheon and Colosseum in Rome. (Irish Concrete Society n.d.). These time laps are shown in figure 5.

Figure 5. History of concrete and its evolution through time. (Bigrentz n.d.)



Modern concrete is based on Portland cement which was patented in 1824 by Joseph Aspdin. At that time mostly concrete-based structures were made. In 1880 prestressing steel was patented and this opened a new era of structures where less concrete was used but with the help of steel strong structures were made.

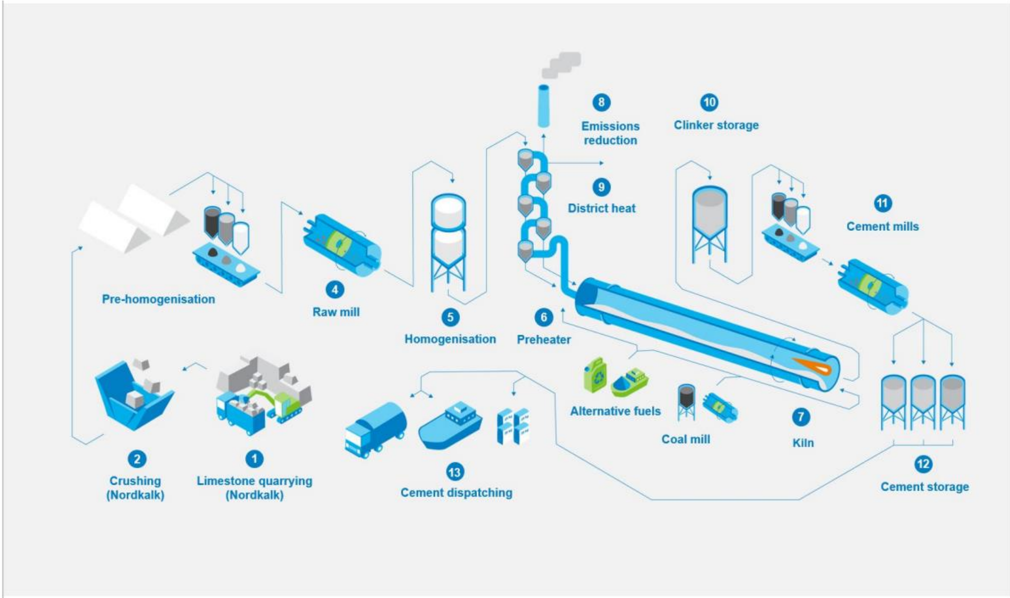
4.2 Cement

The main stages of cement production are:

- Limestone mining, crushing, and raw grinding
- Combustion of Portland clinker
- Cement grinding

In figure 6 this process is shown in detail.

Figure 6. Manufacturing process from quarry to dispatch. (Finnsementti n.d.)



The main raw material for cement production is limestone, which is mined, crushed, and sorted before raw grinding. In addition to the calcium carbonate (CaCO3) obtained from limestone, silicon oxide (SiO2), iron oxide (Fe2O3), and aluminium oxide (Al2O3) are needed in the production of cement, which is obtained from limestone quarry side stones and by-products of other industries. Based on the chemical composition of the aggregates, the feed ratios of the raw materials are determined and the materials are fed into the raw powder mill, where they are finely ground. Figures 7 and 8 show the rotating klin, where most CO_2 generates

Figure 7. Kiln generates the most CO_2 in the production phase. (Dnv.com n.d.)

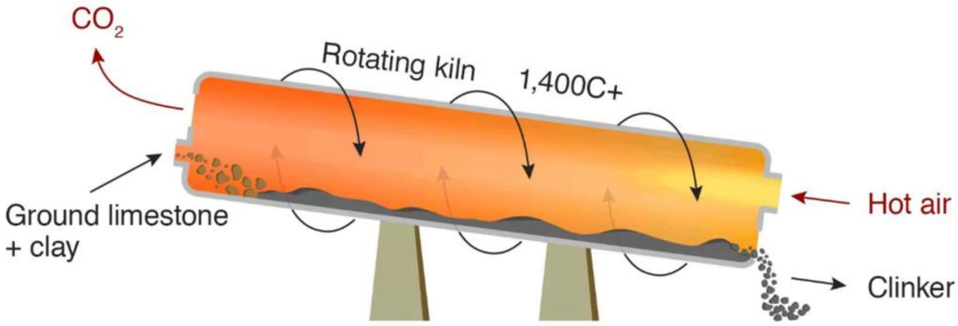
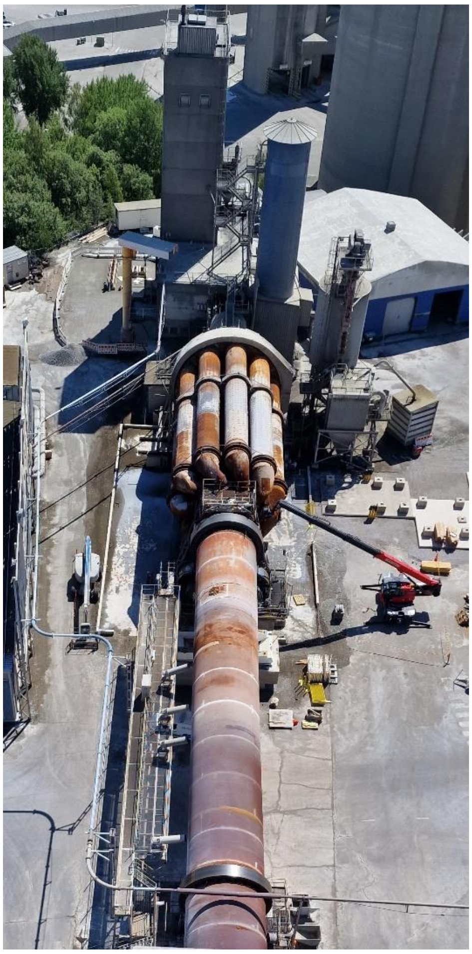


Figure 8. Rotary kiln from Finnsements Pornainen factory.



Cement clinker is produced in a rotary kiln about 100 meters long. The raw powder is fed into the rotary kiln through the cyclone tower, where it heats thanks to the flue gases leaving the kiln. Lime, silicon, aluminium, and iron compounds turn into calcium compounds and sinter into cement clinker when the temperature of the material rises to +1450°C. At the downstream end of the kiln, the cement clinker is quickly cooled to around 200°C in air coolers. At this stage, the clinker resembles coarse gravel.

Building cement is made by grinding clinker, admixtures, and gypsum in a ball mill. At Finnsement, they use limestone and blast furnace slag as admixtures. Gypsum is ground to adjust the setting time of the cement. The properties of building cement are regulated, e.g. with the composition of the clinker, the proportions of the admixtures used, and the grinding fineness. (Finnsementti n.d)

5 Concretes uses in Finland

About half of the concrete used in Finland is prefabricated elements and concrete products from the factory. This provides huge advantages compared to on-site construction. Maintaining the quality of the products made in the factory is more consistent. Environmental harm can be efficiently minimised in factories. By moving the work from the construction site to the factory, lots of disturbances like dust and noise spreading to the environment, as well as traffic problems at the construction site can be reduced. In addition, the construction time can be faster. (Betoni n.d.-A)

In the factory, the production can be diversified by self-compacting concrete, higher concrete strengths, coloured concretes, and other modern technology which can be done with less material loss, with more accurate dimensions, and utilising automation and serial production. This leads to more efficient use of materials and lower manufacturing costs.

5.1 Low-carbon Concrete in Finland

As concrete is the most used building material in the world due to its good and inexpensive properties, its popularity is also based on the fact that the raw materials needed for concrete can be found in almost all countries. In Finland, about 5 million cubic meters of concrete are produced every year, while in the whole world, about 2 cubic meters of concrete are produced for every inhabitant every year. (Betoni n.d.-B)

Few big concreting companies in Finland can deliver ready concrete like Ruskonbetoni, Rudus, and Lujabetoni. Also, small companies can be found too. Almost all of them use finnsementtis products. Upon request, customers can get green concrete too. From the above table, we can see that from global warming potential or GWP.REF means 0% green concrete and it will be found a 15% difference till GWP.40 means 60% green concrete. Usually, the delivered concrete is given details information like C30/37 – #16 mm – S3 - XC3,4, XF1 – 50 v – GWP.85. Figure 9 shows this information in a list.

Figure 9. Classification of low-carbon ready mixed concrete. (Vahahiilinenbetoni n.d.)

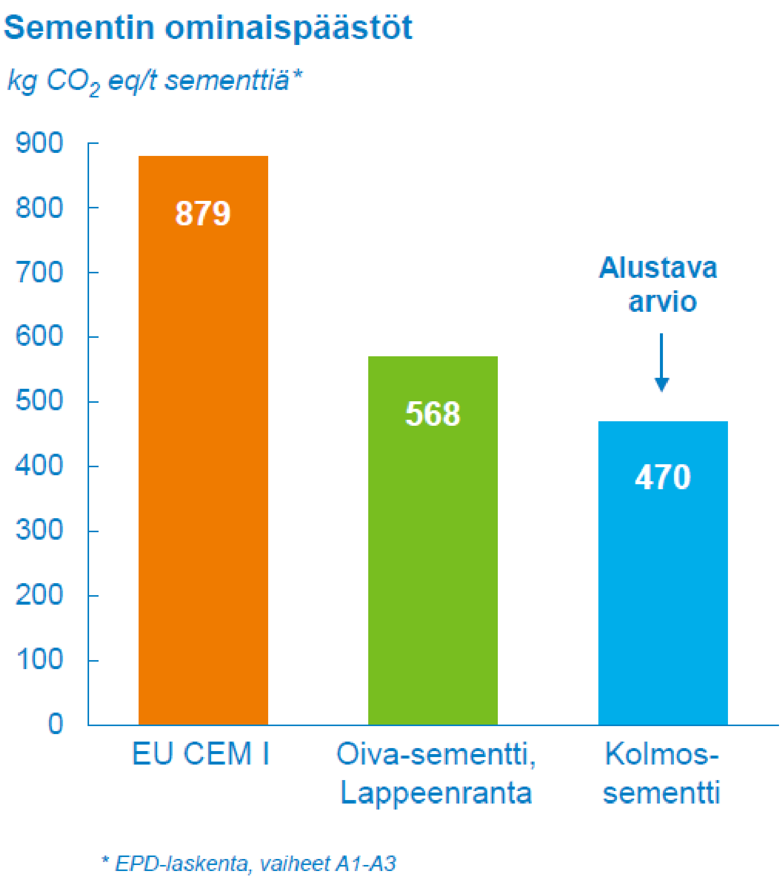
CONCRETE QUALITY	Ref.level GWP.REF	GWP.85	GWP.70	GWP.55	GWP.40
C20/25	210	180	145	115	85
C25/30	230	195	160	125	90
C30/37	255	215	180	140	100
C35/45	285	240	200	155	115
C45/55	320	270	225	175	130
C50/60	340	290	240	185	135
C30/37 - Air-entrained	290	245	205	160	115
C35/45 - Air-entrained	330	280	230	180	130
C45/55 - Air-entrained	375	320	265	205	150
C50/60 - Air-entrained	395	335	275	215	160
C30/37 P0	270	230	190	150	110
C30/37 P30	300	255	210	165	120
C35/45 P0	300	255	210	165	120
C35/45 P30	330	280	230	180	130
C35/45 P50	340	290	240	185	135
C45/55 P50	375	320	265	205	150

As the Finish government is also pushing companies to be carbon neutral, the use of low-emission concrete has grown significantly as nowadays all projects are keeping track of their emission and are also required to have documents from their suppliers and associates. The companies need to show their achievement.

5.2 Low-carbon cement in Finland

One very general mixing ratio of concrete is 1:2:3, where 1 is cement, 2 is sand, and 3 is aggregates. From that mixing ratio, we can say that 1/6 is cement which is about 17%. Now this 17% cement is responsible for almost 50-90% of the total emission of concrete. This is the area where more focus is needed to be carbon neutral. That's why low-carbon bonding materials like fly ash and blast furnace slag are being used in cement.“*The annual carbon dioxide emissions of the Finnish cement industry are about 0.9 million tons out of Finland's total annual emissions of about 50 million tons. For example, in 2018, cement production produced 1.6% of all greenhouse gas emissions in Finland.”* (Betoni n.d.-C). Figure 10 shows emissions from cement.

Figure 10. Carbon dioxide emissions from different types of cement. (Finnsementti n.d.).



“About 1.5 tons of limestone are needed to produce one ton of clinker, which releases about 530 kg of carbon dioxide when burned. The rest of the carbon dioxide comes from fuels. The amount of emitted carbon dioxide has naturally decreased in the same proportion as the

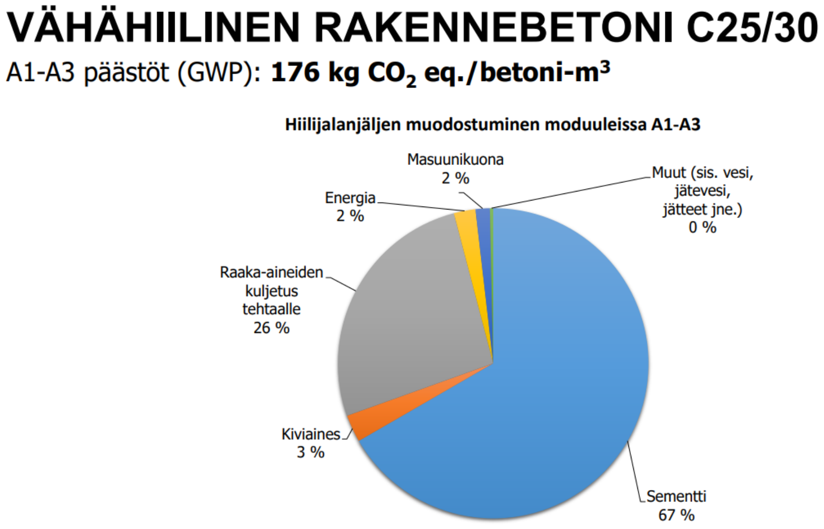
energy efficiency of the ovens has improved. In addition, in recent years fossil fuels have been introduced as energy sources replacing e.g. crushed car tyres, meat bone meal, and packaging waste. In 2021, 45% of the fuel used in the manufacture of Finnish cement was recycled and biofuel." (Betoni n.d.-C)

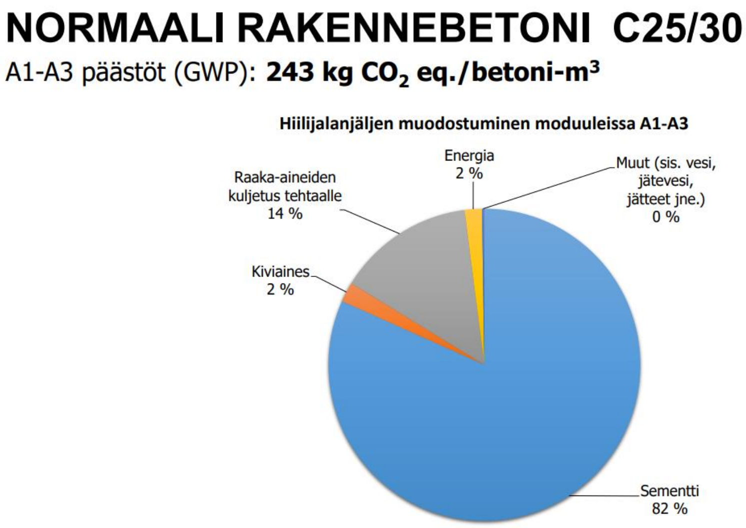
Approximately 350,000 tons of fly ash and blast furnace slag are used in the concrete industry as admixtures in concrete production per year. These fly ashes are coming from burning coal in power plants. Fly ashes help maintain the properties of concretes in both soft and hardened states. It also has the potential to be a fine material or even it can substitute cement in concrete too. Another by-product of the iron industry is blast furnace slug, iron industries produce hundreds of thousands of blast furnace slug. Which is widely used in cement to reduce CO_2 emissions. (Betoni n.d.-C)

Fly ash is used in concrete both as an aggregate to partially replace filler and as a binder. Fly ash has the effect of improving the workability of concrete. In mixed cement, fly ash reduces the heat of hydration in concrete, and then the early strength is also weaker. Due to the slow reaction, fly ash is not recommended for winter or floor castings. Fly ash also affects the porosity of concrete in a weakening way. Additional tests are indeed necessary with additives because their function may change in concrete. (Haara et al. 2018, 56.)

If we can use 30-50% fly ash in our concrete mixture, there is a possibility to reduce carbon emissions by about 10-20%. In the same way, to get even better outcomes regarding the reduction of emissions, there is the possibility to use metal industries by producing blast furnace slag about 40-50%, which can reduce CO_2 emission by about 90%. My strong belief is that, in the coming future this by-product will play a vital role in the emission reduction of cement and concrete industries.
These differences are shown in figure 11.

Figure 11. Comparison of emission of same class cement. (Betoni n.d.)



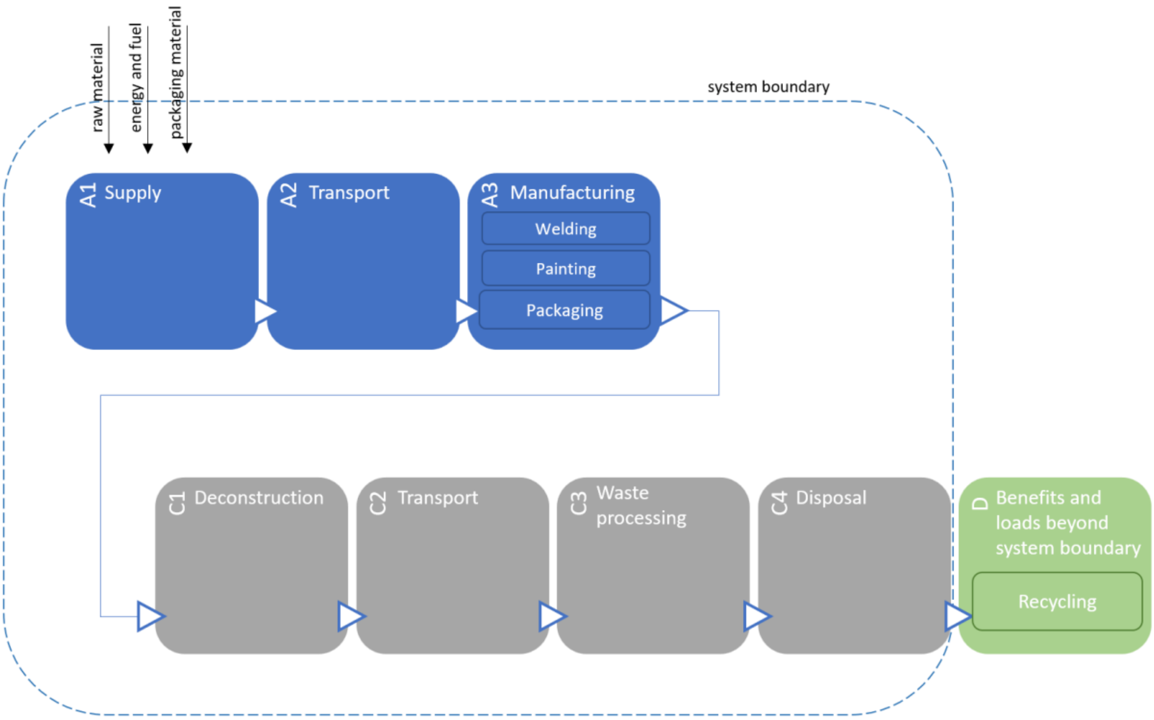


The above pictures graphically show the emission difference of the same class of concrete. From normal construction concrete emission is 243 kg CO_2 eq/m^3 whereas green concrete has the emission of 176 kg CO_2 eq/m^3. That shows that each m^3 can save the emission of 67 kg CO_2 eq. (Betoni n.d.-D)

6 Potential environmental impacts by Suomen Kovabetoni Oy

As an element production company, Suomen Kovabetoni Oy's line of business is related to concrete, which is responsible for the emission of greenhouse gases including CO_2. As a conscious manufacturer, Kovabetoni acknowledges its responsibility for emissions and therefore is trying to make a positive impact on the environment by trying to reduce the emissions and using recycled material. In this study, the environmental impact categories which are determined in the EN 15804 standard were assessed. Figure 12 shows the life cycle modules of materials in Suomen Kovaberoni Oy.

Figure 12. Life cycle modules of materials in Suomen Kovaberoni Oy.



According to the life cycle assessments of the products, module A1 has the most significant impact on the environment due to high volumes of cement and ready-to-use concrete as raw materials: most of the impact comes from cement or ready-to-use concrete manufacturing. Another relevant factor contributing is the use of steel and steel details as raw materials. The amount of contribution of steel to overall results depends on the volume of steel included in the final products. When it comes to transportation, module A2 transports cover around 10- 20 % of total impacts (GWP) for products produced at the

Nastola manufacturing site. On the other hand, the contribution of A2 impacts is minor for products manufactured at the Turku site since the main raw material, ready-to-use concrete is not transported by freight. The end-of-life results hold only a marginal share of overall results.

In the Nastola plants, there is a temporary setup for recycling the waste from the production line. Usually, the waste is collected and stored for some time to gather enough amount, then according to government instruction on a specific time frame crashing of the leftover concrete elements starts. All needed certification is already completed to declare the crushed products as environment-friendly and reusable. 6-12mm are the sizes what will be the aggregate sizes. According to the government's decree about crushed concrete 466/2022, a maximum of 10% can be used in concrete mixtures. This is another way how Suomen Kovabetoni Oy can improve the reduction of emission of CO_2 on their end.

Another important matter is that Suomen Kovabetoni Oy uses CO2-neutral district heating for their factory to reduce the environmental impacts.

7 Research and analysis

One important factor in this fast production of TT-slabs is temperature, as Finland is a cold country and very few months are naturally warm. We must ensure temperatures remain at least 10˚C to cure and reach its desired compressive strength. And it will freeze at -4˚C. If it's too cold, the concrete won't cure at all. For that reason, the production recipe needs to be modified according to the outside temperature. (Linkedin, 2018)

One common practice is to use warm water if slightly warmer water is used in a concrete mixture, which can encourage a quicker reaction and, in turn, a quicker curing time. Hot water should be avoided as this will only damage the concrete mixture.

Another practice is to channel hot water through the casting beds so that the beds get warmer and concrete absorbs the heat to get the kick to start the hydration and reaction process. As Kovabetoni got both of them, that’s a big plus thing for the production of less emissioned products.

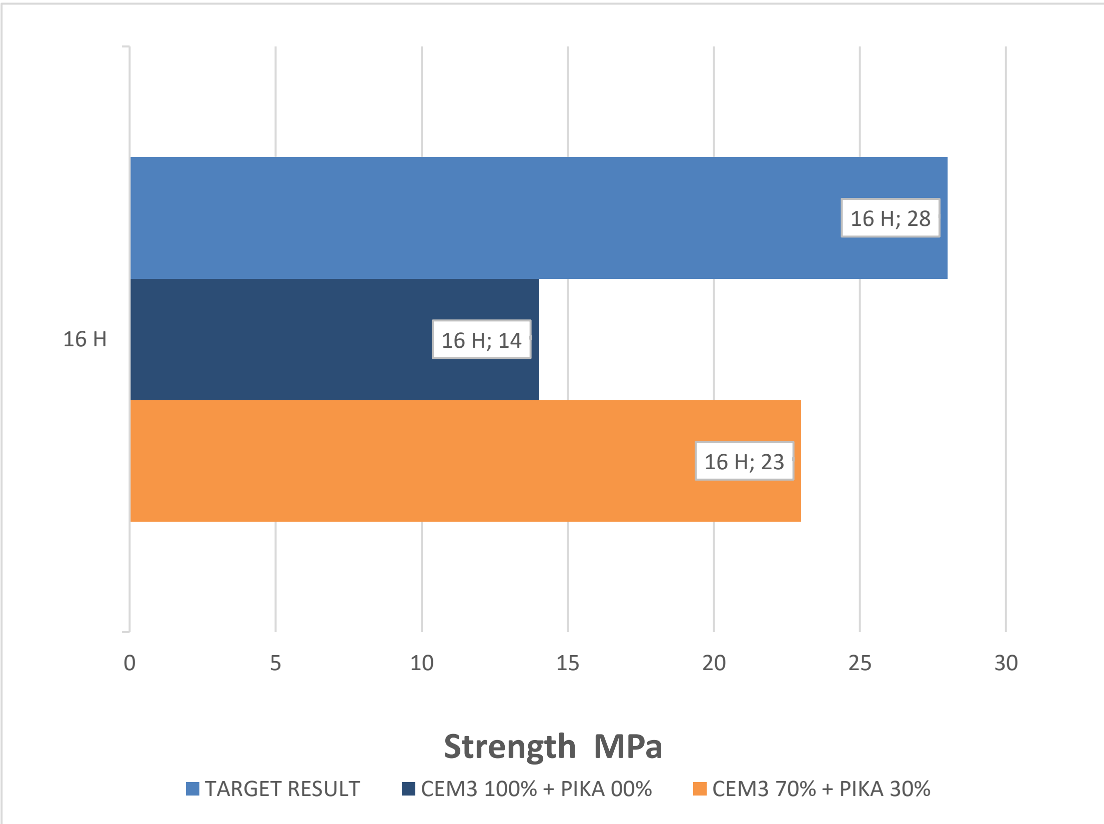
7.1 Strength test: Pillar

Table 1. Result of different cement mixture's strength for pillars

Recipe for pillar	concretes class	Hall temp	MAX concrete temp	Strength at 16H:	Test Result (Needed More than 60% of CC to pass)
CEM3 70% + RAPID 30%	C35/45	20°-25°	52°	**23 MPa** < 28 MPa	FAILED
CEM3 100% + RAPID 00%	C35/45	20°-25°	41°	**14 MPa** < 28 MPa	FAILED

Our focus is on the time frame of 12H-18H to gain 60% of the cubic strength of the used concrete class to speed up production. This test result is concluded based on the earliest removal of elements from the concreting bed. The results are shown in figure 13.

Figure 13. Strength test result of different Pillars concrete mixture at 16 H.



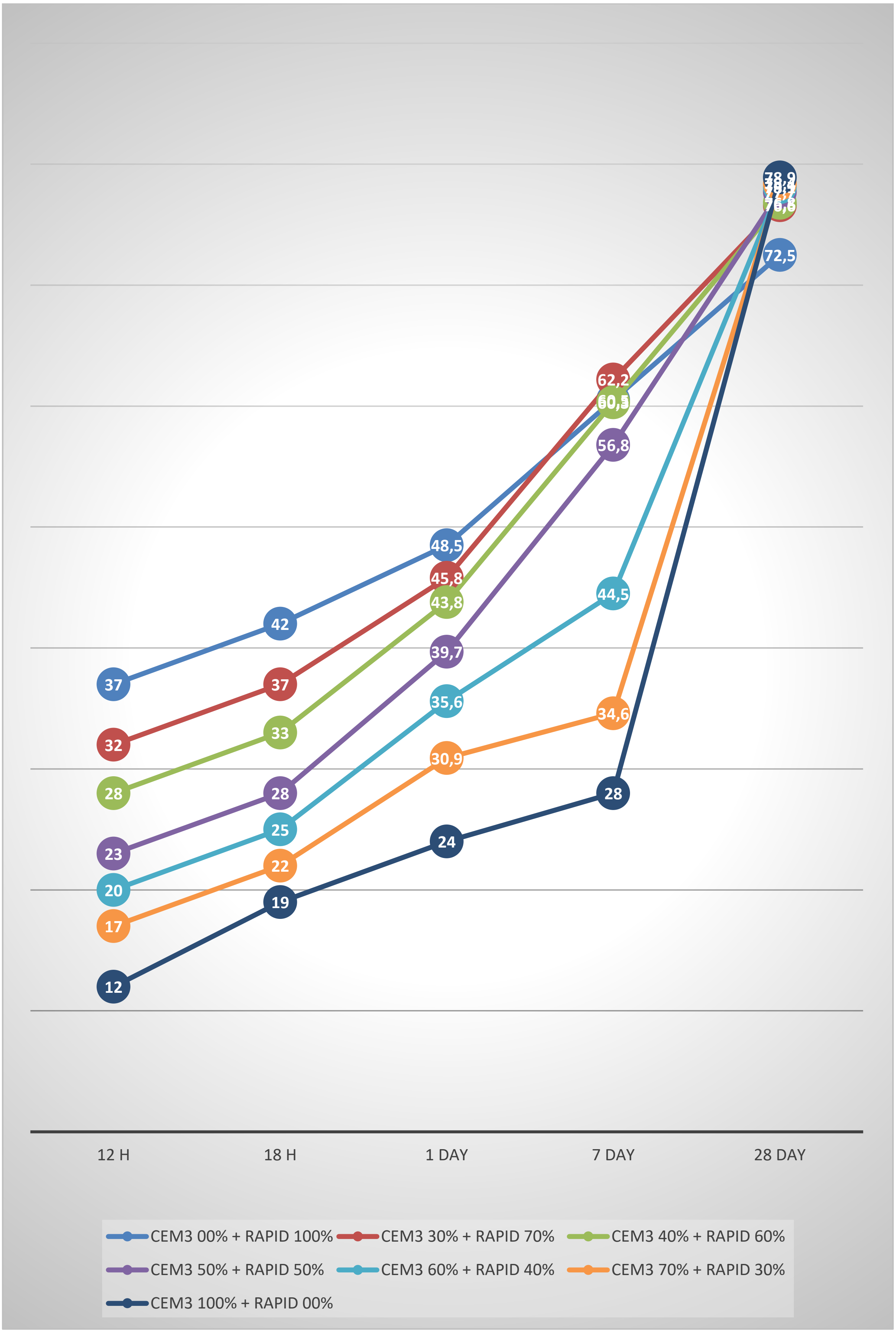
7.2 Strength test: TT-slabs

Table 2. Result of different cement mixtures strength for TT-slabs.

	CEM3 00% + RAPID 100%	CEM3 30% + RAPID 70%	CEM3 40% + RAPID 60%	CEM3 50% + RAPID 50%	CEM3 60% + RAPID 40%	CEM3 70% + RAPID 30%	CEM3 100% + RAPID 00%
Concretes Class	C50/60	C50/60	C50/60	C50/60	C50/60	C50/60	C50/60
Lifting strength (60% OF CC)	> 36MPa	> 36MPa	> 36MPa	> 36MPa	> 36MPa	> 36MPa	> 36MPa
Hall temp.	10°-15°	10°-15°	10°-15°	10°-15°	10°-15°	10°-15°	10°-15°
Concrete mixing temp	25°	25°	25°	25°	25°	25°	25°
Concrete pouring temp	19.8°	19°	19°	19°	20°	20°	20°
12H (MPa)	37	32	28	23	20	17	12
18H (MPa)	42	37	33	28	25	22	19
1Day (MPa)	48,5	45,8	43,8	39,7	35.6	30,9	24
7Day: (MPa)	60,5	62,2	60,3	56,8	44,5	34,6	28
28Day:(MPa)	72,5	76,6	76,8	77,7	78,1	78,4	78,9
Test Result:	PASSED	PASSED	FAILED	FAILED	FAILED	FAILED	FAILED

Our focus has been on the time frame of 12H-18H to gain 60% of the cubic strength of the used concrete class to speed up production. This test result is concluded based on the earliest removal of elements from the concreting bed. The results are shown in figure 14.

Figure 14. Strength test result of different tt-slabs concrete mixture through time.



7.3 Test analysis

The use of blast furnace slag has a softening effect on the concrete, so the need for water is reduced. Blast furnace slag also has a low hydration temperature, and because of this, it works well in massive structures. Like fly ash, using blast furnace slag in cement reduces the early strength of concrete, but the final strength can be even better than when using basic cement. (Haara et al. 2018, 57.)

From Fig 14, we can see that, cement with 100% cem 3 has inferior initial strength in 12H, also the result for 18H is weaker than all other cement, also the outcome is the same on day 1 and day 7 but on day 28 it has the most strength which is 78.9MPa.

Our focus area is on the time frame of 12H-18H to gain 60% of the cubic strength of the used concrete class to speed up the production which is concluded based on the earliest possibility of removal of an element from the concreting bed. Lots of our outcomes are not as expected.

But there are possible ways to get the expected outcomes which will cost time and money. If the element is left to cure longer time, the result is heavily reduced CO_2-emitted elements, which is the opposite of our research.

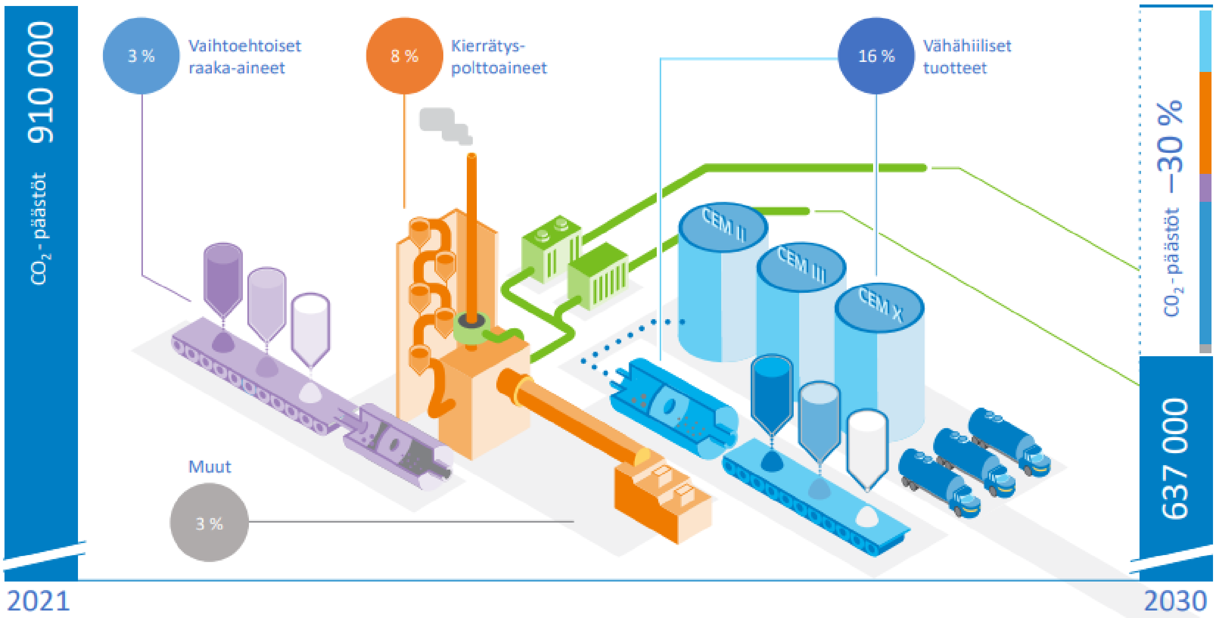
Again, if we don’t want to extend the curing time, then the hall temperatures need to be higher. Which is costly according to the Finland weather situation in wintertime.

8 Future works

This topic is so vast that one person can not cover it all in one paper. There is plenty of room for new research and the development of recipes according to customers' needs. Also, add-mixtures play a vital role. Add-mixtures replace the amount of water to tailor the concrete according to the project and situation. (Engr n.d)

Temperature also plays an important role. To control the temperature in a big hall during the wintertime is tough. But if someone wants to try at a controlled temperature, that can give a positive outcome regarding the reduced CO_2 emission recipe. Regarding this matter of reduction of emissions, Figure 15 shows the vision of Finnsementt and what it wants to achieve by 2030.

Figure 15. Finnsementti's target to achieve by 2030. (Finnsementti n.d)



Suppose anyone feels inspired to focus on different research on the same topic. In that case, different factors can help to achieve the vision faster than expected and even better for the country to achieve its future goal regarding global warming.

9 Conclusion

The emissions of carbon dioxide from green concrete are significantly lower than concrete made with normal cement, so the subject of the thesis, the outcomes of less CO_2 emission cements role in the fast production of concrete elements was very topical. The research work aimed to find out the fast drying time of green concrete to get 60% initial strength and show that it really can be used in mass production by keeping the timeline. To the question "Does low-carbon concrete need a longer drying time than normal concrete of the same strength class, which is commonly used?" the answer for the question is no.

According to research results, the drying of green concrete starts slower, but reaches the same relative humidity readings as normal concrete in the same time frame and the result is better than normal concrete. But as the green concrete drying process starts slower than normal concretes after concreting, there is much to develop to use it regularly without any boundaries for fast and massive production.

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Appendix 1. Additives for readymade concrete

PRO 200

Betonin lisäaineet
Joulukuu 2021

Runsaasti vedentarvetta vähentävä/nesteyttävä lisäaine

PARMIX PRO-200 on Finnsementin kehittämä ja valmistama lisäaine, joka soveltuu erityisesti valmisbetonin tuotantoon.

Ominaisuudet
PARMIX PRO-200:ssa yhdistyvät suuri vedenvähennysteho ja pitkä vaikutusaika. PARMIX PRO-200:n vaikutusaika 20° C:n lämpötilassa on reseptistä riippuen noin 1...1,5 tuntia. PARMIX PRO-200 ei hidasta betonin lujuudenkehitystä eikä sitoutumista. Ominaisuuksiensa ansiosta PARMIX PRO-200 soveltuu erinomaisesti valmisbetonituotantoon sekä käytettäväksi murskatun kiviaineksen kanssa.

Käyttökohteet
PARMIX PRO-200 on polykarboksylaattipohjainen notkistin, joka on tarkoitettu kaikkeen valmisbetoniin, sekä elementtibetoniin kun tarvitaan hieman pidempää työstettävyysaikaa. PARMIX PRO-200 soveltuu käytettäväksi myös murskatun betonin kiviaineksen kanssa. Sitä voidaan käyttää normaalin lujuusluokan, korkealujuus- ja itsestään tiivistyvässä valmisbetonissa. Se sopii myös huokostettuun valmisbetoniin.

Annostus
PARMIX PRO-200 on käyttövalmis neste. Se lisätään betonisekoittimeen joko betoniveden mukana tai valmiiseen betonimassaan. PARMIX PRO-200:n annostus on yleensä 0,3...1,6 % sementin painosta.

Normaalibetoni	0,3...0,8 %
Korkealujuusbetoni	1,0...1,6 %
IT-betoni	1,0...1,6 %

Käyttö muiden lisäaineiden kanssa
PARMIX PRO-200 sopii käytettäväksi yhdessä muiden Finnsementin lisäaineiden kanssa.

Ympäristö ja työturvallisuus
Lue käyttöturvatiedote.

Tekniset tiedot (tyypilliset arvot)

Väri:	Vaalea
Olomuoto:	Neste
Väkevyys:	18,5 %
Perusaine:	Polykarboksylaatti
Käyttölämpötila:	yli +5 °C
Varastointilämpötila:	yli +5 °C
Kloridipitoisuus:	< 0,1 %

Lisätietoja teknisestä neuvonnastamme:
0201 206 200

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Appendix 2. Test results and components of Cem III

Kolmossementti

Sementit
Tammikuu 2022

Korkean 52,5-lujuusluokan masuunikuonasementti — CEM III/A 52,5 L

Sementin ominaisuuksia	Tulokset	Vaatimukset
Puristuslujuus 1 vrk	8...12 MPa	ei vaatimusta
Puristuslujuus 2 vrk	19...23 MPa	≥ 10 MPa
Puristuslujuus 7 vrk	36...41 MPa	ei vaatimusta
Puristuslujuus 28 vrk	59...65 MPa	≥ 52,5 MPa
Sitoutumisaika	150...250 min	≥ 45 min
Tilavuuden pysyvyys	0...1,5 mm	≤ 10 mm
Hienous	450...520 m^2/kg	ei vaatimusta
Hehkutushäviö	0...4 %	≤ 5,0 %
Liukenematon jäännös	0...4 %	≤ 5,0 %
SO_3	3,0...3,5 %	≤ 4,0 %
Kloridipitoisuus	≤ 0,08 %	≤ 0,10 %
Cr6+	0...2 mg/kg	≤ 2 mg/kg

Sementtien sisältämät seosaineet	%	Vaatimus
Yhteensä	40...46 %	≥ 36 % ja ≤ 65 %
Sivuosa-aineet	0...5 %	0...5 %
Masuunikuona	40...46 %	≥ 36 % ja ≤ 65 %

Klinkkerin tyypillinen kemiallinen koostumus	%
CaO	63...65 %
SiO_2	20...22 %
Al_2O_3	4,0...5,4 %
Fe_2O_3	2,8...3,3 %
MgO	2,5...3,2 %

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Appendix 3. Properties of Cem III

Cement 5/2022

Kolmos SEMENTTI

Blast furnace cement
CEM III/A 52,5 L

Kolmossementti is a high-strength blast furnace cement. Mainly used is in ready-mixed concrete, but applications can be found in various concrete products and element applications.

Kolmossementti is also excellent for stabilization. The high amount of GGBFS makes it an environmentally friendly

Cement properties	Requirements (SFS-EN 197-1)
Strength 2 d	≥ 10 MPa
Strength 28 d	≥ 52,5 MPa
Initial setting time	≥ 45 min
Soundness	≤ 10 mm
Loss on ingnition	≤ 5%
Insoluble residue	≤ 5%
SO_3	≤ 4,0%
Chloride content	≤ 0,10%
Cr6+	≤ 2 mg/kg

Cement composition	Requirements (SFS-EN 197-1)
Cement clinker	≥ 35% and ≤ 64%
GGBFS	≥ 36% and ≤ 65%

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