MINIMISATION OF CARBON DIOXIDE EMISSION BY REDUCING CEMENT IN A CONCRETE SYSTEM THROUGH MECALITHE® TECHNOLOGY

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Introduction

This study eventually targets to reduce cement quantities in a Mecalithe® based pre-cast concrete system and compare its strength with that of standard recipes for multifaceted advantages. Greenhouse gas CO_2 which contributes to global warming, is reduced simultaneously. Reduction of CO_2 gas is considered valuable because CO_2 is a potential greenhouse gas which tends to absorb and then emit radiant energy within the thermal infrared range.[1] Global warming is seen as a big challenge and it must be controlled now, otherwise - as has been predicted - by 2047[2] CO_2 levels will cross critical levels, with potential harmful effects on the eco-system, biodiversity and human existence itself. Global Carbon dioxide emission from 1850-2030, shows the level of CO_2 emissions approaching critical levels (Figure 2).[3]

Cement production stands at the third-largest source of anthropogenic emission of CO_2[1], which is around 8% of the global CO_2 emission and in a production process of 1 ton of Portland cement, an emission of approx. 927 kg of CO_2 is generated. The CO_2 is generated from 3 independent sources: (1) decarbonisation of limestone (approx. 525 kg CO_2/ton of clinker), stoichiometry indicates CO_2 quantities released for a given amount of CaO produced; (2) combustion of fuel (approx. 335 kg CO_2/ton of cement); (3) the use of electricity (approx. 67 kg CO_2 /ton of cement). In total, this amounts to approx. 927 kg of CO_2/ton of cement produced.[2] Values for the CO_2 emission of CEM II and CEM III can be calculated from the amount of clinker present in the cement. The CO_2 emission of CEM II with 80% of Portland cement is 155 kg per ton, for CEM III with 65% of Portland cement this is 603 kg per ton cement, these calculations relate to percentage of clinker present.

Accordingly, concrete samples with Mecalithe® and with 35% less cement with different water-cement-factor (wcf), have been prepared in the GreenCem BV Research Lab. The compressive strength (CS-N/mm^2) that is achieved in 24 hrs and 28 days has been compared with that of original and standard pre-fab concrete samples without Mecalithe®. The percentage gain in strength has been calculated

with CS of the standard concrete samples in 28 days as a reference. Please see, “Materials and Methods” for further details.

Materials

Standard sand (0-4) mm - 55%, gravel (2-8 mm) - 45%, CEM II 52.5 N and CEM III/B 42.5 N, Mecalithe® (25 kg/m^3), Mecalithe® activator (2.5 kg/m^3) and fillers from re-cycled material (100 kg/m^3) were used, as available in The Netherlands.

Methods

A standard recipe from pre-cast concrete, containing 115 kg/m^3 of CEM II 52.5 N and 115 kg/m^3 CEM III/B 42.5 N with no Mecalithe® was taken as a reference. In the Mecalithe® test recipes, all ingredients were the same as that of the standard recipe, except cement was reduced to 80 kg/m^3 of CEM II 52.5 N and 85 kg/m^3 of CEM III/B 42.5 N. (28% reduction). The wcf has ranged from 0.72 to 1.03 (Table 1). All ingredients were mixed in the mixing unit for approx. 30 sec., water was added while mixing for 60 sec. and prisms were made. Curing was at 20 +/- 2 $^{\circ}$C. The density was determined according to NEN-EN 12390-7. The prisms were tested for CS according to NEN-EN12390-3 at 24 hrs, 7 and 28 days.

Results and Discussion

The CS for the standard mixture with a cement quantity of 230 kg/m^3 yielded 7.44 N/mm^2 in 24 hours and 23.76 N/mm^2 in 28 days. Test samples with Mecalithe® and 28% less cement (Compared to standard), yielded 5.12 N/mm^2 in 24 hours and 27.16 N/mm^2 in 28 days (Table 1). It is significant to mention that at an optimised wcf of 1.0 the strength of Mecalithe® recipe is 31.18% lower (after 24 hours) as compared to standard but eventually in 28 days, the Mecalithe® recipe with low cement content had gained extra strength of 14.30% over the standard (Table 1, item3). It is of value to observe that the compressive strength with Mecalithe® test recipe which had 28% less cement and having 31.18% lower strength in 24 hours, gained enormous strength in 28 days and was eventually jumped to achieved 14.30% extra strength.

Mecalithe® recipe with 28% less cement had 14.30% extra strength in 28 days, which provides an opportunity to explore further possibilities of more cement reduction in these recipes. CO_2 reduction, if CS of the standard and Mecalithe® taken as equal, will yield a reduction of 44 kg/m^3 of CO_2. On the basis of these results, future experiments can be designed to ascertain if there is a possibility of reducing cement lower than 165 kg/m^3 in a Mecalithe® recipe. These results are surely encouraging and in future further reduction in cement content is expected through Mecalithe® Technology.

Table 1: Density (kg/m^3) and compressive strength (N/mm^2)

	Cement	wcf	Density	24 hours	7 days	28 days
Standard	115+115	0.72	2245	7.44	23.12	23.76
1	85+80	0.90	2237	4.88	16.52	24.24
2	85+80	0.95	2237	5.76	11.08	25.24
3	85+80	1.0	2237	5.12	15.88	27.16
4	85+80	1.0	2237	4.68	14.84	24.20
5	85+80	1.03	2237	3.96	13.80	19.60
6	95+95	1.03	2214	3.48	13.84	19.60

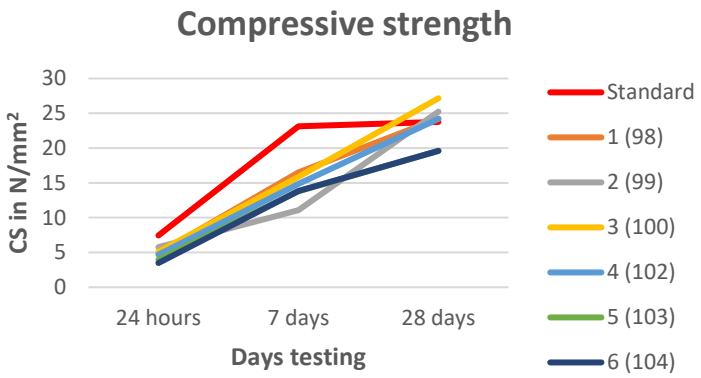

Figure 1: Compressive strength (N/mm2)

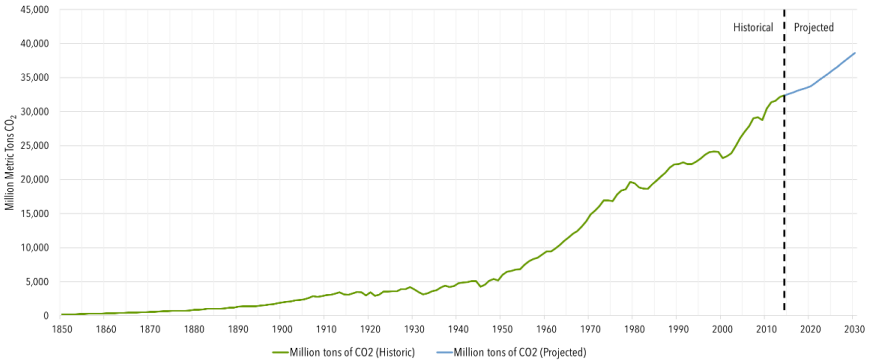

Figure 2: Global Carbon Dioxide Emissions 1850-2030[3]

Table 2: Reduction of CO_2 emission

Parameters	Quantity (kg/m^3)
Cement (standard)	230 kg/m^3
CO_2 emission (standard)	155 kg/m^3
Cement used in tests (reduced cement)	165 kg/m^3
CO_2 emission in tests (reduced cement)	111 kg/m^3
Saving in cement (kg/m^3)	65 kg/m^3
Reduction in CO_2 emission	44 kg/m^3

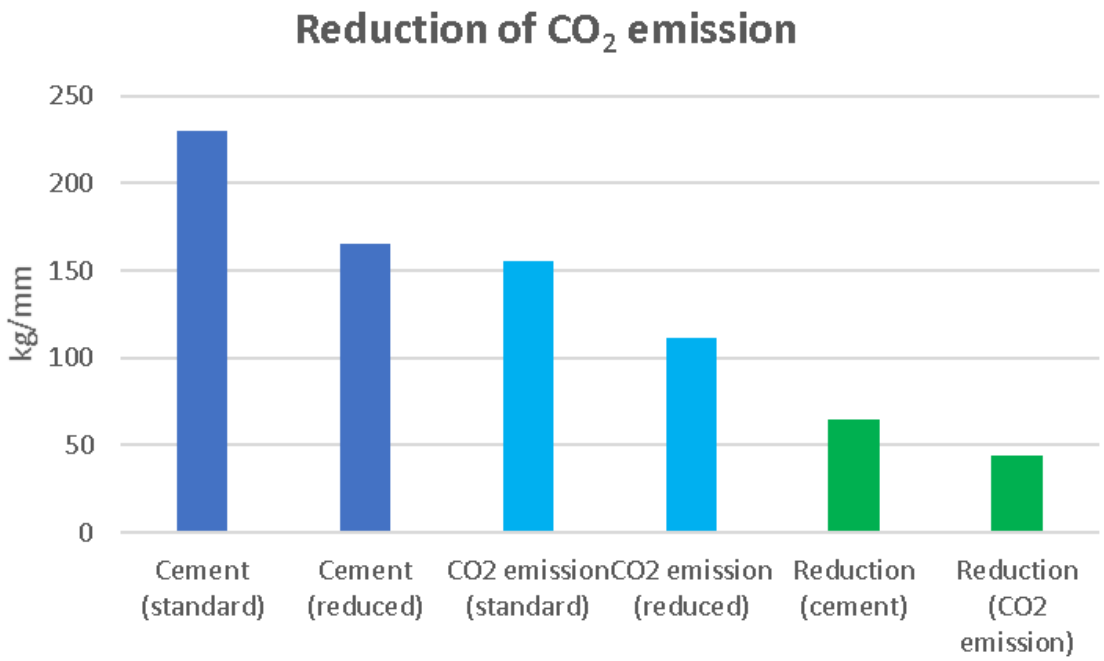

Figure 3: Reduction of CO_2 emission

Conclusions

1. This study reveals that 65 kg/m^3 of cement reduction is achieved through Mecalithe® Technology on the basis of strength development in 28 days.
2. The compressive strength with a standard mixture and a Mecalithe® recipe with 28% less cement had 23.76 and 27.16 N/mm^2 respectively in 28 days, achieving 14.3% extra strength.
3. This leads to reduction in CO_2 emissions of 44 kg/m^3 with possibilities of enhancement of these values with more research.
4. This adds to saving in cement quantities, reduction in CO_2 emission, cost reduction on account of use of less cement, its transportation, storage and handling costs *etc.*
5. Control of greenhouse gas CO_2 leads to containment of global warming, is seen as a step towards sustainable environmental protection.

References

1. R. M. Andrew, Global CO_2 emission from cement production, CICERO Centre for International Climate Research, Oslo, Published 26th January 2018;
2. M. J. Gibbs (Reviewed by Dina Kruger (USEPA), "CO_2 emissions from cement production", Good Practice and uncertainty Management in National Greenhouse Gas Inventories, 1996.
3. C. Mora, "The projected timing of climate departure from recent variability", *Nature*, **502** (7470) 183-187 (2013).