

Use of toxic waste as aggregate to produce eco-friendly concrete without reinforcement in sludgy areas for minimising waste and atmospheric CO₂ using Mecalithe® Technology

Introduction

Mecalithe® Technology has been used in this study for minimizing toxic and non-toxic waste to produce eco-friendly green concrete to be used in sludgy and loose formations. This is innovative and specialised concrete (called Spijkerbed) as it is produced to hang on concrete poles with segmented calculated spacing, so that the produced concrete does not sink into the loose formation. This study, conforms to waste reduction, like the Dutch government will commit that in 2030 50% and in 2050 100% of all materials will be re-used. Critical elements are to make concrete in land below sea level (Figure 2) and load distribution and pole spacing. The concept of Spijkerbed is used in a number of locations – all located in the lowest part of The Netherlands. A modern lifestyle, alongside the advancement in industry has led to an increase in the amount and type of waste being generated, leading to a waste disposal crisis². But this is a potential step in waste disposal and environmental technology.

In a traditional concrete system 350 kg/m³ of CEM I (Portland) is used with sand and gravel as aggregates with a significant amount of steel-reinforcement. Mecalithe® based concrete uses only 180 kg/m³ of slack based cement (48% cement reduction), only recycled toxic and non-toxic wastes are used as aggregate and despite the fact that there is a huge spacing of poles by ~3 m, still no steel reinforcement is used. This is cost-effective because of the low cement system; also waste as aggregate brings money (negative cost) and most importantly this leads to a substantial reduction in atmospheric greenhouse gas CO₂.

Extensive lab experiments have been conducted over a period of time and the techno-economic viability is established by constructing >90,000 m² Mecalithe® based working floor concrete and top layer concrete at Moordrecht, Groot Ammers, Gouda, Waddinxveen¹ and Reeuwijk etc. The study includes life cycle analysis for CO₂, quality/strength parameters (CS/BS/D), leaching of 15 metals and 5 non-metals and organics according to NEN/NEN-EN norms. Lab findings have been implemented in the fields.

Specialised value addition

This study has distinct specialised elements which are: a) use of 100% re-cycled toxic and non-toxic waste, as a substitute of sand and gravel; b) 48% reduced cement causing reduction in atmospheric CO₂; c) no reinforcement steel used while spacing of poles of 3 meter apart, causing reduction in atmospheric CO₂.

Materials and Methods

Mecalithe® Technology, which consists of a well-researched chemical formulation, was used to develop in the research lab as a prototype model to be used in the field applications. This technology was used in the production of (1) Working floor; (2) Deck Plate. Two types of wastes were used in the production of the working floor and 3-4 different types of hazardous and non-hazardous wastes were used in production of the Deck Plate. Slack cement CEM III 42.5/B LH/HS was mixed with Mecalithe® powder and water based slurry was produced to make concrete mixtures.

Results and Discussion

A critical element of the study is to qualify leaching parameters which contains 15 metals ions and 4 non-metal ions in a diffusion test (DT-NEN 7375) according to BRL 9322/AP04 which is valid for both the working floor and the deck plate from field samples of Moordrecht, Groot Ammers, Gouda, Waddinxveen¹ and Reeuwijk etc. This is a mandatory legal requirement, according to the norms. All field samples passed but only one example is provided here for a general overview¹, it is due to limitations of space - Table 1.

Load distribution applied on concrete makes the bending strength (BS) and compressive strength (CS) very critical because of the balance of load applied on the deck plate. Mecalithe® formulation through chemical mechanism leads to BS is 4.76 - 5.02 N/mm² and CS is 22 - 27 N/mm² for the deck plate at 180 kg/m³ cement and to CS 6 - 8 N/mm² for the working floor at 150 kg/m³ cement (tables 2 and 3). The quantification of saving of CO₂ emissions is represented in Figure 1. Mecalithe® has potentials to reduce cement with different cement types (CEM I and CEM III with different % of clinker). The traditional concept of using steel reinforcement in Spijkerbed constructions has been avoided due to the use of Mecalithe® formulations, thus further reducing CO₂ emissions. 1.65 kg CO₂ per kg steel is saved³.

Table 2: Working Floor: CS (N/mm²) and Density in 28 days (conforms to BRL 9322)

Tested	Height (mm)	Diameter (mm)	Weight (g)	Density (Kg/m ³)	CS (N/mm ²)
Proctor	115 - 120	98 - 100	1,681 - 1,726	1,837 - 1,926	6 - 8 N/mm ²

Table 3: Deck Plate CS (N/mm²) BS (N/mm²) Density 28 days (Conforms to BRL9322)

Tested	Height mm	Width mm	Weight gram	Ultra Sound m/s	Density kg/m ³	CS N/mm ²	BS N/mm ²
Cube	~150	~150	7,130 - 7,326	4,116 - 3,873	2,138 - 2,167	22 - 27	4.76 - 5.02

Reduction in atmospheric greenhouse gas CO₂ due to reduced cement and using no reinforcement

CO₂ emission plays an important role in the control of our environment. There is a constant pressure to reduce the CO₂ emission. One of the most important sources for CO₂ emission is the concrete industry, with cement as the most dominant part. By using Mecalithe® less cement can be used to produce concrete with the same strength. In Figure 1 the CO₂ emission for various types of concrete is shown compared with a reduced use of cement in combination with Mecalithe®.

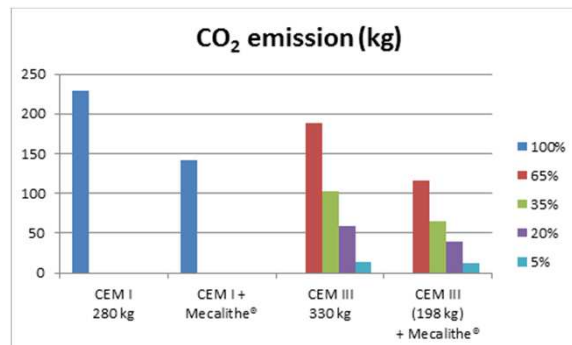


Figure 1: Graphical Reduction in atmospheric greenhouse gas CO₂ due to reduced cement and using no reinforcement (CEM III with different percentages of clinker) compensation by using wood in concrete

If reinforcement is used one can also choose to lower the amount of cement less, but also use less or no reinforcement. This will save 1.65 kg CO₂ per kg steel.

Table 1: DT NEN 7375, SAM AP04 and LS10 NEN-EN 12457 chemical analysis of proctors showing leaching profile of 15 metals and 4 anions (representative example - Waddinxveen)¹

	DT, NEN 7375 mg/m ²		SAM AP04 mg/kg ds ³		LS10, NEN-EN 12457 mg/kg ds ³	
	limit ¹	result ²	Result	limit ¹	result ²	
As	260	1.92	10	0.9	0.050	
Cd	3.80	0.05	0.99	0.04	0.0010	
Cr	120	0.49	36	0.63	0.017	
Cu	98	8.71	99	0.9	1.5	
Hg	1.40	0.02	0.10	0.02	0.00050	
Ni	81	2.40	35	0.44	0.29	
Pb	400	2.40	210	2.3	0.10	
Sn	800	4.80	370	4.5	0.30	
Ba	1500	28	320	22	1.1	
Co	60	1.44	7.1	0.54	0.036	
Mo	144	8.69	3.7	1	0.65	
Sb	8.70	1.18	9.1	0.16	0.015	
Se	4.80	0.66	4.2	0.15	0.035	
Sn	50	1.44	8.4	0.4	0.030	
V	320	7.31	40	1.8	0.60	
Fluoride	2,500	101	-	55	1.9	
Bromide	670	38	-	20	1.4	
Chloride	110,000	9,666	-	616	310	
Sulphate	165,000	80,573	-	1,730	16,000	

¹Maximum emission value in 64 days in mg/m²

²Measured cumulative leaching in 64 days in mg/m²

³ds = dry soil



Figure 2: Water level critical



Figure 3: Construction of poles



Figure 4: Work in progress



Figure 5: Final construction

Conclusions:

Mecalithe® Technology has been used to use toxic and non-toxic waste as a replacement of traditionally used sand and gravel both in working floor and deck plate (Spijkerbed). 48% cement reduction and without steel reinforcement makes the whole concept eco-friendly by massive reduction in CO₂ emissions. Absence of steel reinforcement makes the study techno-economically an excellent technology. Water level is higher than construction so making working floor with concrete is challenging, all working floors were hardened Figure 2. Poles were spaced according to engineering calculations Figure 3; Figure 4 and 5 shows construction progress and final floor (Deck Plate); Passing all the leaching parameters and achieving CS of 22 - 27 N/mm² and BS of 4.76 - 5.02 N/mm² makes the technology a potential option in over-all environmental protection.