Development of Sustainable 3D Printable Ternary Composite

Alise SAPATA, Maris SINKA, Genadijs SAHMENKO, Liga PUZULE, Peteris SLOSBERGS

3D concrete scientific laboratory, Institute of Materials and Structures, Riga Technical University

RIGA TECHNICAL UNIVERSITY

Contact information:

1 Paula Valdena street,
Riga, LV-1048, Latvia
maris.sinka@rtu.lv

An innovative approach for reusing gypsum to develop a ternary material suitable for 3D printing, aiming to reduce CO2 emissions by up to 20% compared to Portland cement mortar. Sustainable gypsum-cement-pozzolanic ternary binder composites suitable for exterior environments are developed by incorporating up to 55% recycled materials of the binder mass.

Fig. 1. A small-scale printed object using one of the developed GCP mixtures, indicating good buildability.

Introduction

This research presents an innovative approach for **reusing gypsum** to develop a material suitable for 3D printing, with the goal to **industrialize** the usage of **waste gypsum** in civil engineering.

The gypsum-cement-pozzolanic (GCP) ternary composite combines the **quick setting time** of **gypsum**, **high** final **strength** of Portland **cement**, with a crucial **pozzolanic** component that ensures **chemical stability**.

Materials and Methods

Within the framework of this research, **five ternary composites** were developed.

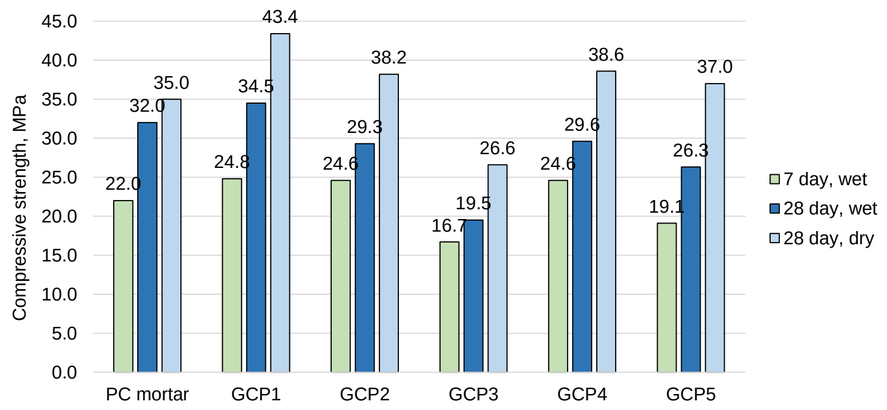
Table 1. Proportions of GCP composites, expressed in grams per 1 kilogram of dry mass.

	PC mortar	GCP-1	GCP-2	GCP-3	GCP-4	GCP-5
Gypsum, Baugyps, *Knauf*	0.0	366.7	183.3	0.0	0.0	0.0
CDG gypsum	0.0	0.0	183.3	366.7	0.0	183.3
Phosphogypsum	0.0	0.0	0.0	0.0	366.7	183.3
CEM I 42.5, N, *Schwenk*	303.0	150.0	150.0	150.0	150.0	150.0
Metakaolin	0.0	150.0	150.0	150.0	150.0	150.0
Limestone	202.0	0.0	0.0	0.0	0.0	0.0
Water	151.5	303.3	356.7	411.0	350.0	400.0
Retarded powder	0.0	3.3	3.3	3.3	3.3	3.3
Admixtures	10.1	0.0	0.0	0.0	0.0	0.0
Sand, fr. 0…2mm	494.9	333.3	333.3	333.3	333.3	333.3

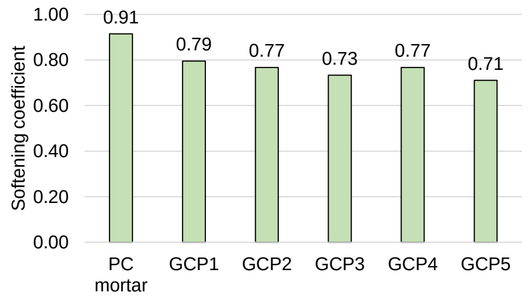
The developed GCP composites contain commercially available gypsum as well as **recycled** industrial waste **gypsum materials**, such as **construction demolition waste gypsum** (CDG) and phosphogypsum (PG).
CDG is obtained as a **secondary product** from gypsum board utilization since gypsum is **infinitely recyclable.**
PG, an **industrial byproduct**, is only 15% recycled for building materials and agricultural fertilizers, with the rest ending up in **waste piles**, posing **environmental risks.**

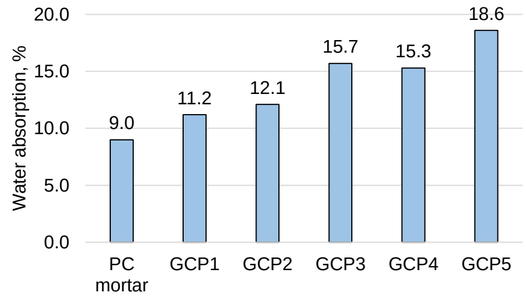
Results and Conclusions

Optimized GCP composition has a **compressive strength** of **45 MPa** in **dry** conditions and **35 MPa** in **wet** conditions.

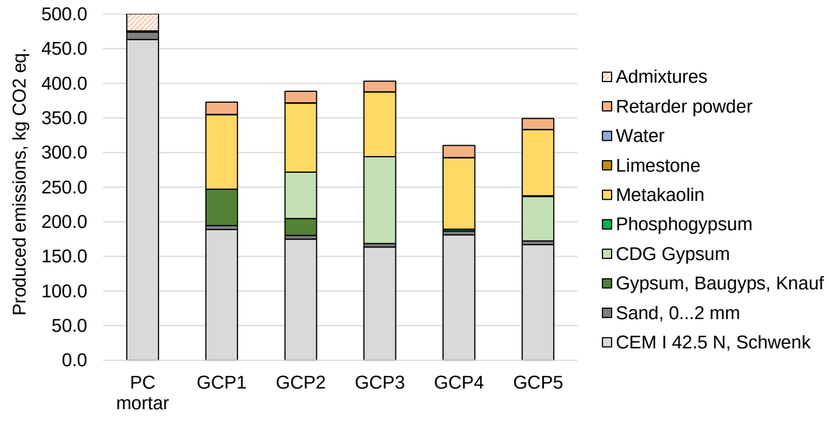


The **softening coefficient** remained **above 0.70** for all mixtures. Mixtures containing gypsum and up to 50% recycled gypsum showed low **water absorption** of **less than 15%.** The obtained values indicates that the developed mixtures are **suitable for** use in **exterior environments**.





Life cycle assessment of GCP compositions shows a **decrease** of up to **20%** in **carbon dioxide emissions**, compared to PC mortar.



This research is funded by the FLPP (Fundamental and Applied Research Projects) Program in Latvia under the research project LZP-2022/1-0585 “Development and Characterization of Sustainable Gypsum-Cement-Pozzolanic Ternary Compositions for 3D Printing”.