Green thinking in the ceramic industry-porcelain stoneware tiles from low-impact raw materials

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NEW CIRCULAR BUSINESS CONCEPTS FOR THE PREDICTIVE AND DYNAMIC ENVIRONMENTAL AND SOCIAL DESIGN OF THE ECONOMIC ACTIVITIES

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TIMETABLE

Action		2017				2018				2019				2020				2021				2022			
Action numbe	Name of the action	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
A. Preparatory actions (if needed)																									
B. Implementation actions (obligatory)																									
B.1	Design of a dynamic LCA+LCC+SLCA tool				■	■	■	■	■	■	■														
B.2	Customization of the ERP module								■	■	■	■	■												
B.3	Design of materials and processes for sustainable ceramic tiles								■	■	■	■	■	■	■	■									
B.4	Prototyping of sustainable ceramic tiles													■	■	■									
B.5	Verification of technological conformity									■	■	■	■	■	■	■									
B.6	Integration of LCA, LCC and SLCA for sustainable decision making model					■	■	■	■	■	■	■	■	■	■	■									
B.7	Replicability of the dynamic model and transferability to another type of production													■	■	■									
C. Monitoring of the impact of the project actions (obligatory)																									
C.1	Monitoring of the impact of project actions					■	■	■	■	■	■	■	■	■	■	■									
D. Public awareness and dissemination of results (obligatory)																									
D.1	Communication and Dissemination				■	■	■	■	■	■	■	■	■	■	■	■									
E. Project management (obligatory)																									
E.1	Overall project management by GRESMALT				■	■	■	■	■	■	■	■	■	■	■	■									

The purpose of this action is the design of a porcelain tile composition containing at least 20-30 wt.% of raw materials delivered by rail instead of by road, leading to a lower environmental impact of the final product. Nowadays, clay raw materials for ceramic production in the Sassuolo district (Italy) are supplied by several different transportation modes including rail, road and water although road transportation is the most common one. To limit road transport, at least in Europe, one viable way is to use German clays delivered by train. Currently, porcelain stoneware tile compositions mainly contain high-quality clays from Ukraine and Germany, with limited amounts of clays of lower quality from Spain, Portugal and national territory. To satisfy the market trend, increasingly oriented towards the use of large formats (40x80, 60x120, 120x240cm), the properties of the clay component in the raw materials mixture is very important. In fact, high mechanical strength in the green state becomes crucial in order to avoid mechanical damage during glazing and decoration. From this point of view, the Ukrainian clay is preferred due to its high plasticity. Another important advantage is its high fusibility. Taking all this into account and to pursue the aim of the action, the research was focused on characterizing the technological properties of German clays transported by rail and including them in novel formulations.

AIMS OF WORK

- **Individuate and characterize German clays available on the market**
- **Formulate novel compositions by partially substituting the Ukraine clays with German ones**

RAW MATERIALS and NOVEL MIXTURES

Table 1: Chemical and mineralogical compositions (wt%) of german (TED) and UK clays used in the study

Oxide	UK	TED1	TED2	TED3	TED4	TED5
SiO_2	58.5	65.8	67.0	65.6	59.8	67.7
Al_2O_3	27.5	21.3	21.0	21.0	24.0	20.4
Fe_2O_3	1.5	1.2	1.2	2.0	2.1	1.6
TiO_2	1.3	1.4	1.2	1.6	2.4	1.5
MgO	0.5	0.4	0.5	0.2	0.7	0.5
CaO	0.3	0.2	0.2	0.2	0.5	0.3
Na_2O	0.6	0.0	0.1	0.1	0.1	0.1
K_2O	2.6	1.8	2.1	2.3	1.7	1.9
LOI	7.2	7.5	6.2	6.3	8.6	6.2
Phase						
quartz	25	40	40	38	30	39
illite	30	23	23	24	21	25
kaolinite	43	34	35	35	46	36
others	2	3	2	3	3	2

The mineralogical compositions of the German clays are different with respect to that of the Ukraine clay, the former ones being more kaolinitic and the latter one more illitic. The ukraine clay is more rich in Na2O which acts as flux. This is an important aspect to consider when formulating new mixtures.

Table 3: new mixtures containing #5 TED clay

	Industrial mix	MT8	K3	FL5
Ukraine clay	25	15	25	25
German clay	10	15	20	25
Turkish Na-feldspar	20	35	22	38
Italian K-feldspar	20	/	23	5
Italian sand	25	/	10	7
Feldspar sand	/	35	/	/
SiO_2	70.7	70.7	69.6	67.4
Al_2O_3	17.7	17.7	18.6	20.3
Fe_2O_3	1.0	0.7	1.0	1.0
TiO_2	0.6	0.6	0.7	0.8
MgO	0.4	0.4	0.4	0.4
CaO	0.6	0.5	0.7	0.8
K_2O	2.8	2.4	2.8	1.7
Na_2O	2.6	4.2	2.4	3.8
LOI	3.6	2.8	3.8	3.8

Table 2: Chemical compositions (wt%) of the raw materials used in the study

Oxide	Ukraine clay	German clay	Turkish Na-feldspar	Italian K-feldspar	Italian sand	Feldspar sand
SiO_2	58.5	67.7	69.5	77.0	79.9	78.5
Al_2O_3	27.5	20.4	18.5	12.5	10.2	11.5
Fe_2O_3	1.5	1.6	0.2	0.9	0.8	0.6
TiO_2	1.3	1.5	0.3	0.1	0.2	0.1
MgO	0.5	0.5	0.4	0.1	0.4	0.4
CaO	0.3	0.3	1.0	0.1	3.4	0.3
Na_2O	0.6	0.1	10.0	0.5	1.5	2.5
K_2O	2.6	1.9	0.5	7.0	0.8	4.5
LOI	7.2	6.2	0.5	1.8	2.8	1.8

The preliminary investigations show that the German clays have similar technological properties but are different from the Ukrainian clay (not shown here). Following the same grinding process, the Ukrainian clay is finer (residue 0.8 %) and has higher fluxing action (water absorption 0.02%) and linear firing shrinkage (8.5 %). Also the viscosity measured with the Ford cup is higher, possibly indicating a higher plasticity. These results show that a simple substitution of the Ukrainian clay with German ones are not possible without changing the technological properties. An alternative approach is to completely reformulate the raw materials mixture, by matching the chemistry of the novel formulation with the standard containing the Ukrainian clay, particularly concerning the Na/K ratio. This work is the second part of the action. Table 2 shows the chemical compositions of the raw materials used for the novel formulations, including the German clay nr.5 which was found most suitable. In particular, three different compositions were investigated having a higher Na_2O (MT8), lower SiO_2 (FL5) and equal (K3) Na/K ratio with respect to the standard industrial composition. The obtained results allowed to deeper understand the changes in sintering behavior induced by the introduction of the German clay. The raw materials mixtures were wet grinded using standard laboratory equipment (65 wt.% dry material and 35 wt.% water) until a solid residue <5 wt.% was achieved (45 µm sieve). The powder obtained from drying the slip was humidified to 6 wt.% and uniaxially pressed (470 kg/cm^2) to obtain cylinders with a diameter of 50 mm. Following firing in an industrial kiln, some technological properties were determined as shown in Table 4.

RESULTS

Table 4: technological parameters of the studied mixtures (Buller 1100°C)

Mixture	WA %	Linear shrinkage (%)	Linear thermal expansion (%)
Industrial	0.43	5.5	0.2
MT8	1.73	5.7	-0.3
K3	0.35	5.0	0.9
FL5	0.43	6.6	0

CONCLUSIONS

The preliminary results presented here show that the sintering behavior of the mixture containing 20 wt.% of German clay (K3) is similar to that observed for the standard industrial mixture. In fact, the technological parameters differ less than 10% from the standard. Instead, the water absorption and the linear firing shrinkage of MT8 and FL5, respectively, are too high. We can thus conclude that the composition K3 best satisfies the purpose of this action, being the design of a porcelain stoneware tile formulation containing at least 20 wt.% of raw materials transported on rail.

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