Co-utilization of construction and demolition with industrial wastes for the production of geopolymers

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Objective

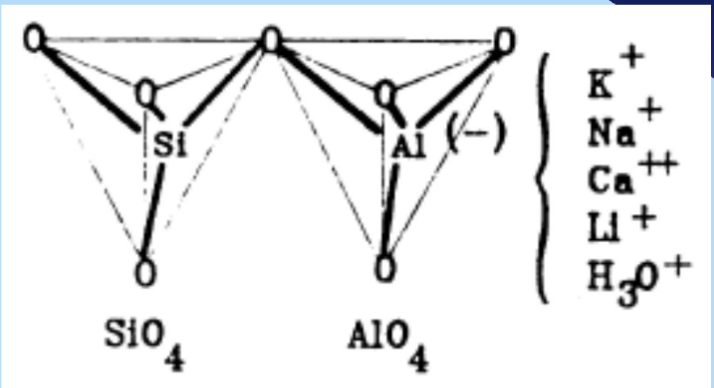
Investigation of the co-geopolymerization potential of the construction/demolition wastes (tiles, bricks and concrete) with fly ash, electric arc furnace slag and red mud

Contents

- Geopolymerization
- Materials and experimental methodology
- Co-geopolymerisation of CDW and a) fly ash, b) ferronickel slag, c) red mud
- Characterization and morphology of the specimens
- Conclusions

Geopolymers

- Geopolymers are cementitious inorganic materials formed by the alkali activation of aluminosilicates at relatively low temperatures
- Partially or fully amorphous polymeric structures consisting of Si–O–Al bonds
- The tetrahedral AlO_4 and SiO_4 units are built in three dimensional structures



Geopolymerization

- The structure and mechanical properties of geopolymers are affected by several parameters
- The potential of various industrial wastes such as fly ash, slag and red mud for the production of geopolymers has been investigated extensively during the last 25 years
- The synthesis of geopolymers using construction/demolition wastes (CDW) still remains a challenge and a limited number of studies have been carried out so far

Raw materials

[aluminosilicate materials or industrial by-products]

+

Activating solution

[KOH or NaOH and Na_2SiO_3]

Materials

- Electric arc furnace slag from the "LARCO S.A" ferronickel plant

- CDW (tiles, bricks and concrete)

- Fly ash from the Megalopolis power station

- Red mud from "Aluminium of Greece"

Table 1. Particle size (µm) of raw materials

	Tiles (T)	Bricks (B)	Concrete (C)	Fly ash (F)	Slag (S)	Red mud (R)
size	<140	<140	<190	<121	<120	<76
d_{50}	14	7	10	10	12	4

Table 2. Chemical composition (%) of the raw materials

Component	Tiles (T)	Bricks (B)	Concrete (C)	Fly ash (F)	Slag (S)	Red mud (R)
SiO_2	70.54	57.79	5.81	47.68	32.74	9.28
Al_2O_3	9.80	14.95	1.49	18.44	8.32	15.83
CaO	8.78	8.79	65.42	9.94	3.73	10.53
Fe_2O_3	5.39	6.00	0.75	7.52	43.83	41.65
Na_2O	-	1.03	0.57	0.37	-	2.26
K_2O	1.37	2.80	1.26	1.44	-	0.21
MgO	4.46	4.75	4.21	2.65	2.76	1.13
MnO	0.06	0.05	0.01	-	0.41	-
P_2O_5	-	0.23	0.73	0.28	-	0.12
SO_3	-	-	0.82	2.76	0.45	0.3
TiO_2	0.77	0.85	0.03	0.76	-	4.73
Cr_2O_3	-	-	-	-	3.07	-
CO_2	-	-	-	3.87	0.40	-
LOI	0.23	1.89	21.59	4.3	-	16.77
Total	101.40	99.13	102.69	100.1	95.71	102.81

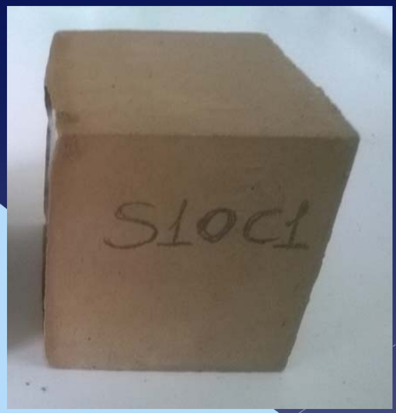
LOI: Loss on ignition after heating the material at 1050 ^oC for 4 h

Experimental methodology

- The activating solution consists of NaOH anhydrous pellets, distilled water and sodium silicate solution
- Raw materials are mixed with the activating solution (6, 8 or 10 M NaOH). Control specimens were prepared by mixing each waste alone with the activating solution.
- The specimens produced (5 cm edge) were heated at 80 or 90 °C in a laboratory oven for 7 days and then subjected to compressive strength testing using a Matest C123N load frame
- X-ray diffraction (XRD) (Bruker D8 Advance diffractometer)
- Fourier transform infrared spectroscopy (FTIR) on KBr pellets (Perkin–Elmer Spectrum 1000 spectrometer)
- SEM analysis (JEOL 6380LV scanning electron microscope)

Geopolymers from concrete, bricks and tiles (left to right)

Tiles-red mud geopolymers

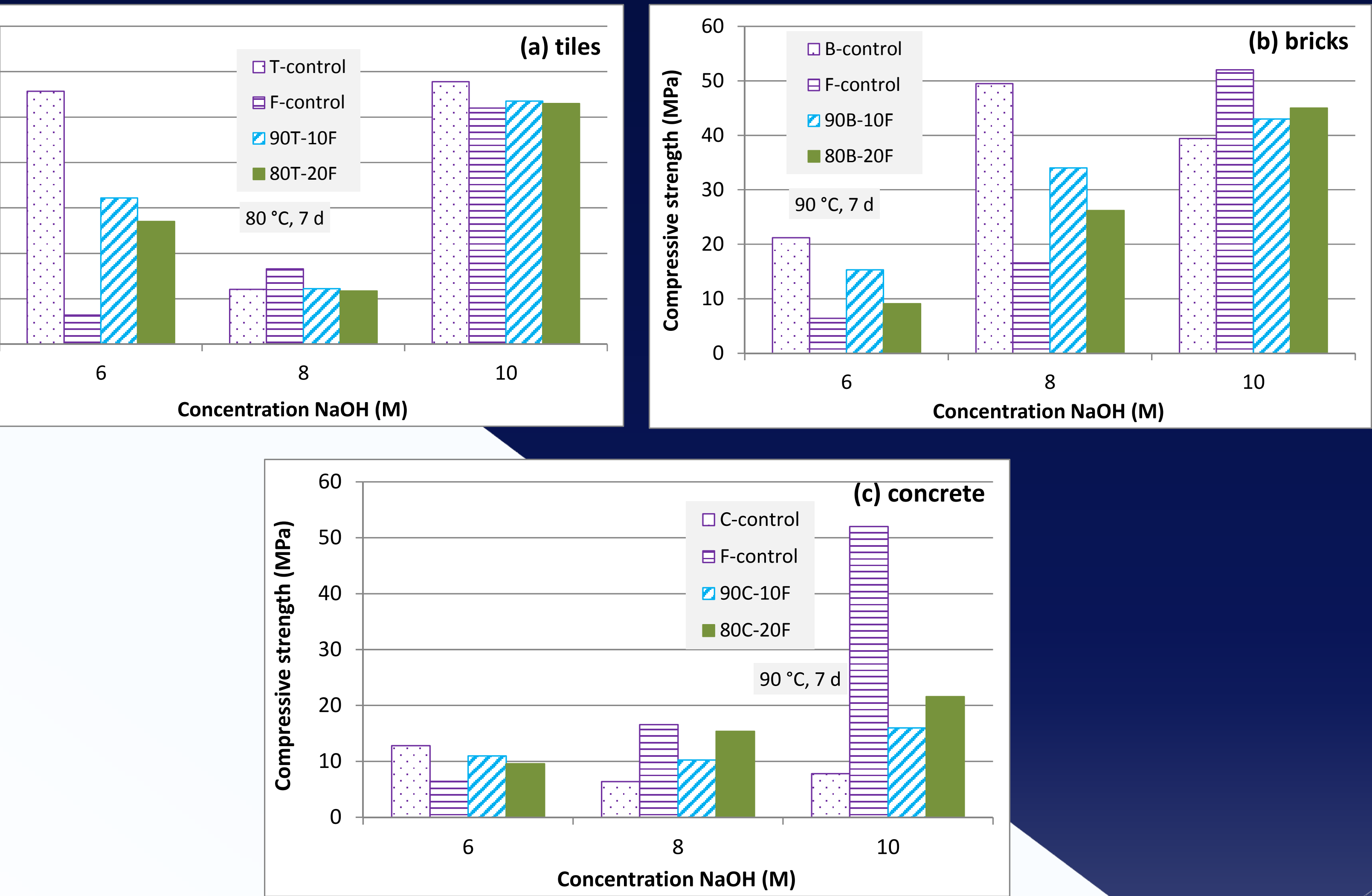


CDW-slag geopolymer

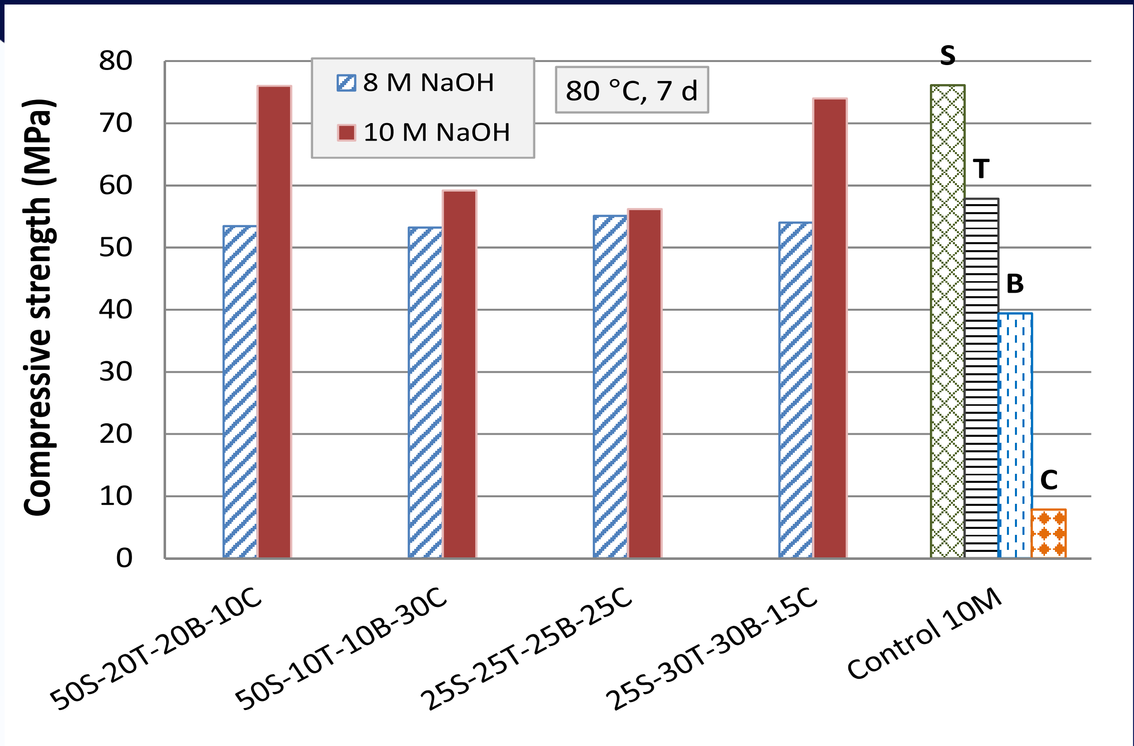
Results and discussion

ble 3. Molar ratios of oxides of the initial paste for the synthesis of selected geopolymers (10 M NaOH)

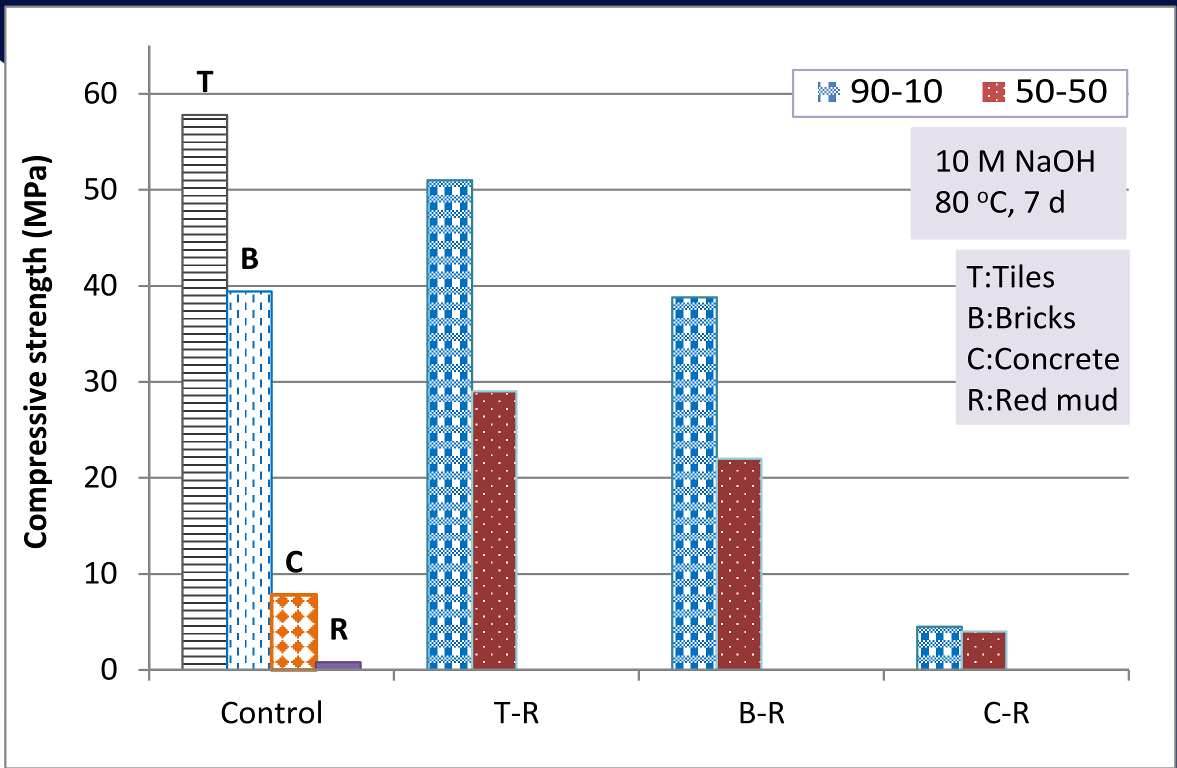
	MPa	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{(Al_2O_3 + CaO)}$	$\frac{H_2O}{(Na_2O + K_2O)}$	$\frac{(Na_2O + K_2O)}{SiO_2}$	$\frac{SiO_2}{(Al_2O_3 + Fe_2O_3)}$
	57.8	12.67	4.81	9.03	0.12	9.38
	39.4	6.84	3.30	8.32	0.14	5.44
	7.8	9.86	0.12	6.62	1.53	7.47
	52.0	4.70	2.37	8.95	0.22	3.73
	76.1	7.33	4.03	8.30	0.10	1.68
	0.9	1.33	0.60	8.11	0.96	0.50
T-20F	53.0	10.51	4.28	9.06	0.14	10.57
B-20F	45.0	6.41	3.12	7.50	0.17	6.48
C-20F	21.6	5.91	0.24	8.40	0.54	5.93
S-10T-10B-30C	59.2	8.26	1.18	6.96	0.14	2.67
S-30T-30B-15C	74.0	8.86	2.21	6.10	0.10	4.54
T-10R	51.0	10.83	4.22	8.55	0.10	6.98
T-50R	29.0	5.60	2.36	8.22	0.21	2.58
B-10R	38.8	6.24	2.99	7.19	0.17	4.44
B-50R	22.0	3.98	1.86	7.54	0.28	2.00
C-10R	7.0	5.07	0.13	8.50	1.07	2.47
C-50R	4.0	2.01	0.22	8.24	0.99	0.79



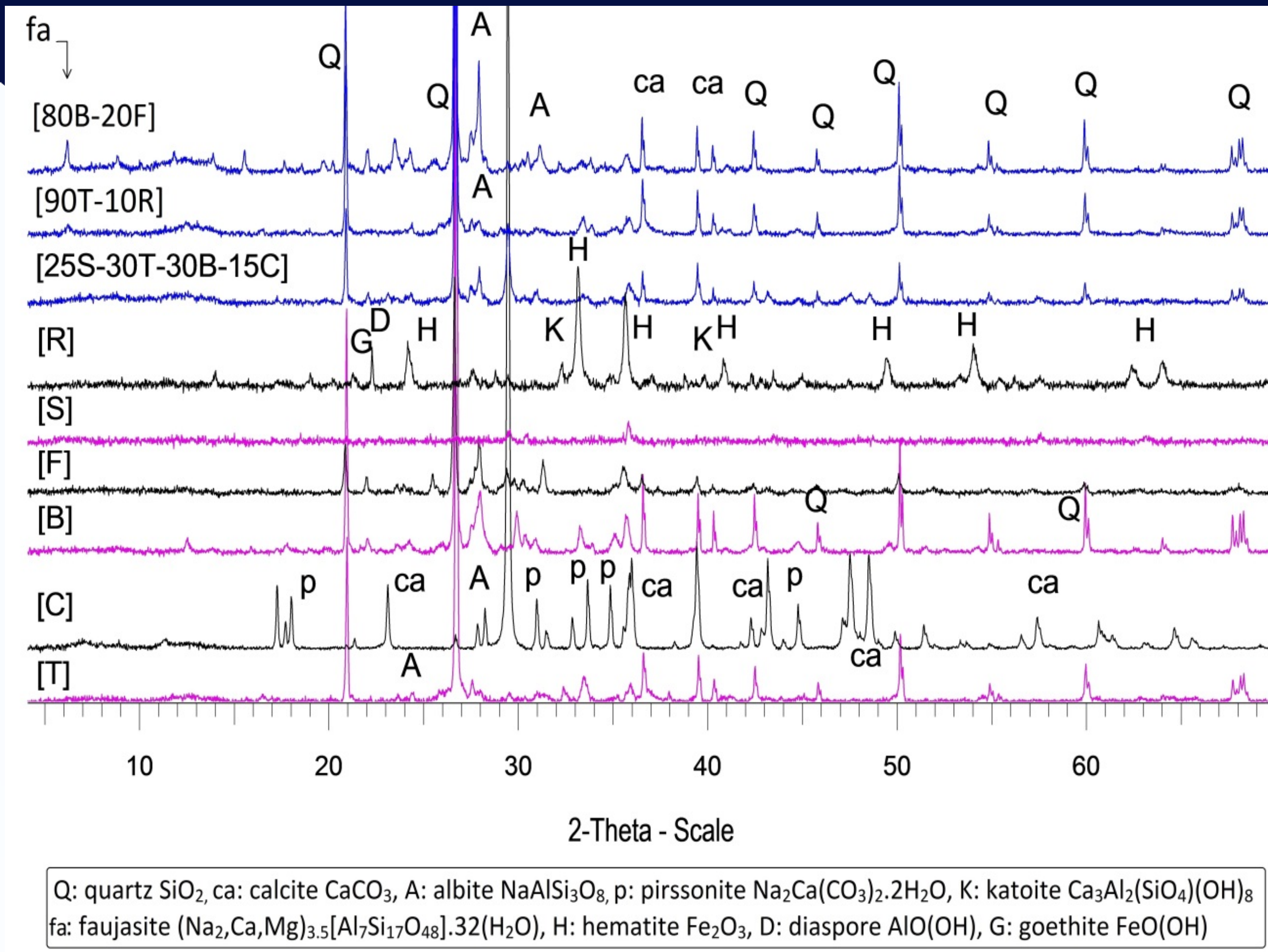
re 1. Compressive strength of geopolymers prepared by mixing (a) tiles, (b)



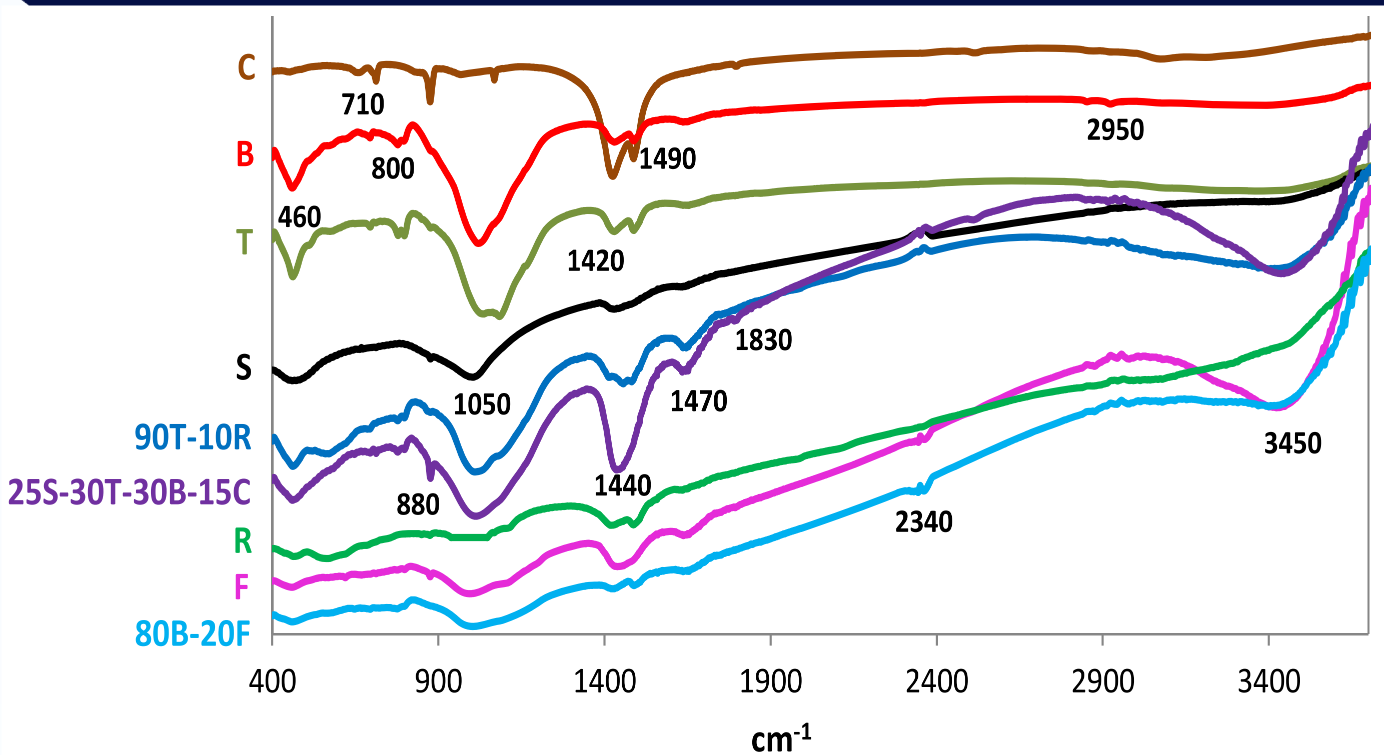
2. Compressive strength of geopolymers prepared by mixing CDW with slag
ious percentages (eg. 50S-20T-20B-10C: % w/w 50 slag-20 tiles-20 bricks-10
concrete)



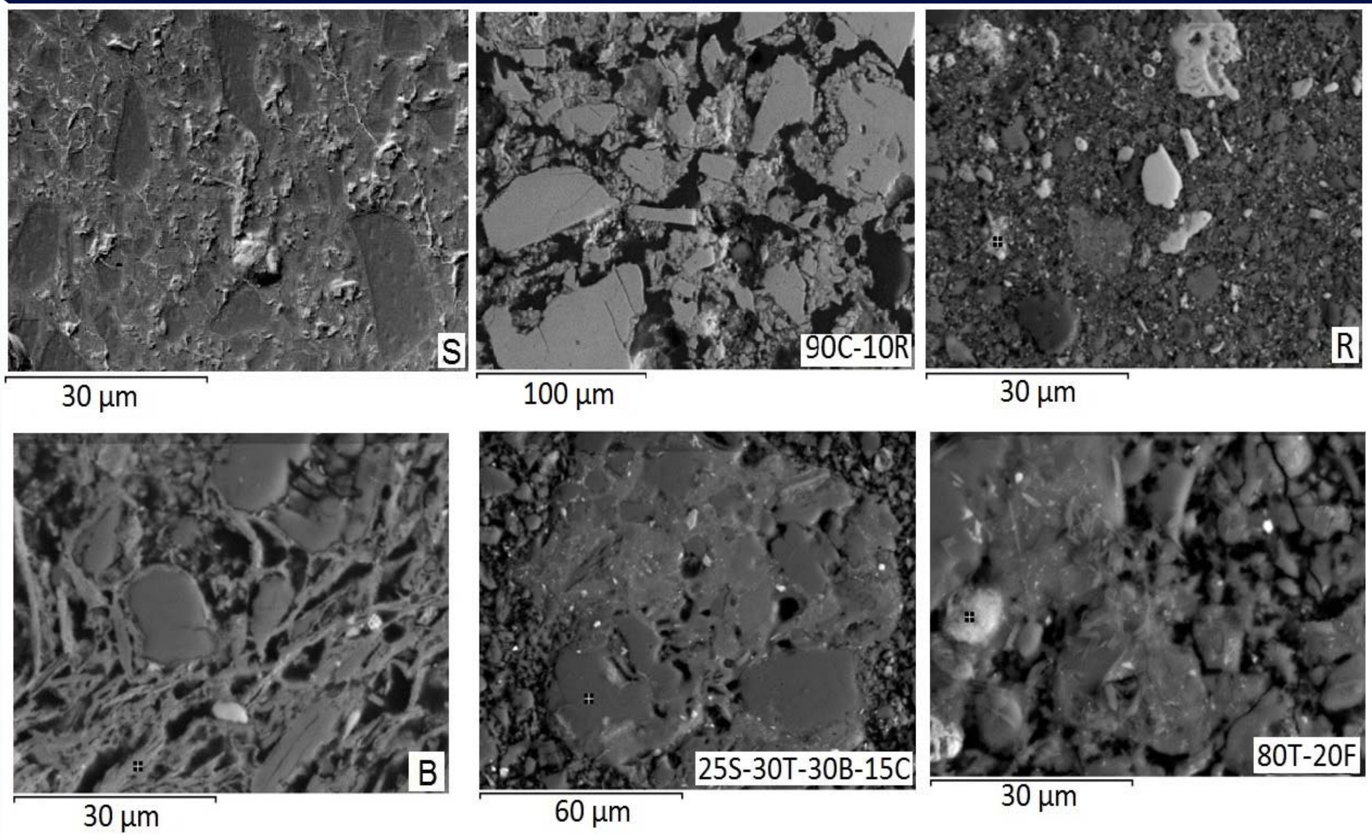
3. Compressive strength of geopolymers prepared by mixing tiles (T), bricks and concrete (C) with red mud (R) at % w/w 90-10 and 50-50, respectively



ure 4. XRD patterns of selected geopolymers synthesized from CDW and



gure 5. FTIR spectra of selected geopolymers synthesized from CDW and ustrial wastes (B: bricks, T: tiles, C: concrete, F: fly ash, S: slag, R: red mud)



6. SEM images of selected geopolymers synthesized from CDW and industrial wastes (B: bricks, T: tiles, C: concrete, F: fly ash, S: slag, R: red mud)

nclusions

everal industrial wastes, namely fly ash, slag and red mud an be successfully co-geopolymerised with CDW

he best geopolymerisation potential is shown for eopolymers prepared by mixing % w/w:

- ✓ *50 slag-20 tiles-20 bricks-10 concrete (76 MPa)*
- ✓ *90 tiles-10 fly ash (54 MPa)*
- ✓ *90 tiles-10 red mud (51 MPa)*

he strength increase of geopolymers is related to the:

- ✓ *high SiO_2 and Al_2O_3 and low CaO content*
- ✓ *increased molarity of the activating solution (optimum:*

nclusions

RD, FTIR and SEM analyses provide very useful insights on he microstructure and the characterization of the roduced geopolymers

Major fingerprints of the aluminosilicate geopolymeric natrix - FTIR analysis

pecimens prepared using bricks, tiles, slag and fly ash are haracterized by a quite homogeneous matrix - SEM tudies

he formation of pirssonite as a result of atmospheric arbonation is an indication of low strength geopolymers -

nk you

l University of Crete
f Mineral Resources Engineering
h unit "Management of Mining/Metallurgical Wastes and Rehabilitation of
inated Soils" [*http://www.mred.tuc.gr/3020.html*](http://www.mred.tuc.gr/3020.html)

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