Development of an Innovative Insulation Fire Resistant Façade

from the Construction and Demolition Waste

DEFEAT

INTEGRATED/0918/0052

DELIVERABLE D4.2

DATA SHEET OF CONCRETE AND CERAMIC WASTE STREAMS

The Project DEFEAT (INTEGRATED/0918/0052) has been co-funded by the European Regional Development Fund (ERDF) and the Cyprus Government, through the RESTART 2016-20 framework program of the Cyprus Research & Innovation.Foundation

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SUMMARY

The general objective of the DEFEAT project is the strategic separation and transformation of Construction and Demolition Wastes (CDW) into an innovative insulation fire resistant façade. The management of CDW in Cyprus faces several challenges and appears to be underperforming, despite the fact that a comprehensive legislative framework concerning the management of CDW is in place since 2011.

Work Package 4 (WP4) of this research programme is led by the University of Cyprus (UCY) who is the strategic partner responsible for the management, timely execution, completion and delivery of the required outputs. The WP4 targets a comprehensive set of generic characterization techniques conducted on as-received samples of CDW from different sources in order to investigate their full chemical and mineralogical composition which is a crucial step towards the development of the end product.

This datasheet aims to provide a comprehensive understanding of the physio-chemical and mineralogical properties of the examined materials.

This document should be consulted in conjunction with D4.1 prepared by the consortium in line with the outputs and deliverables of WP4.

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1. PARTICLE SIZE ANALYSIS

1.1. Summary and key features

Particle size analyses and distributions were done using a combination of Fraunhover and Rayleigh and Mie scattering model (Figures 2 to 4).

The materials have their peak value of their percentage volume approximately within the range of 60-80 microns.

A slight volume increases at 1 micron size is followed by a 0.5% volume reduction at the regime between 2 and 3 microns.

Past the peak, the volume fractions are decreased in the samples reaching zero at around 200-300 microns.

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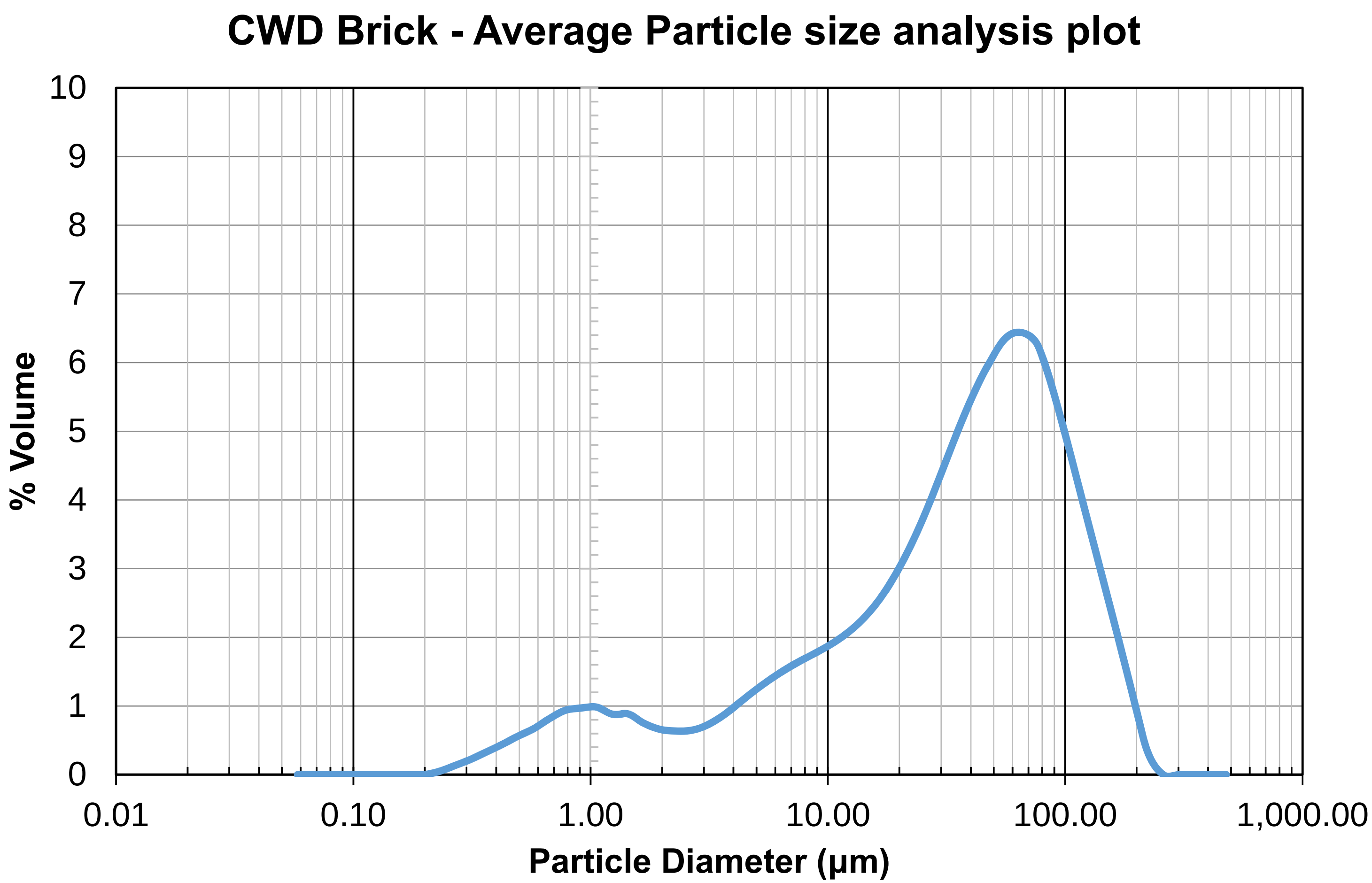

Figure 1. Average particle size analysis for the CWD brick material.

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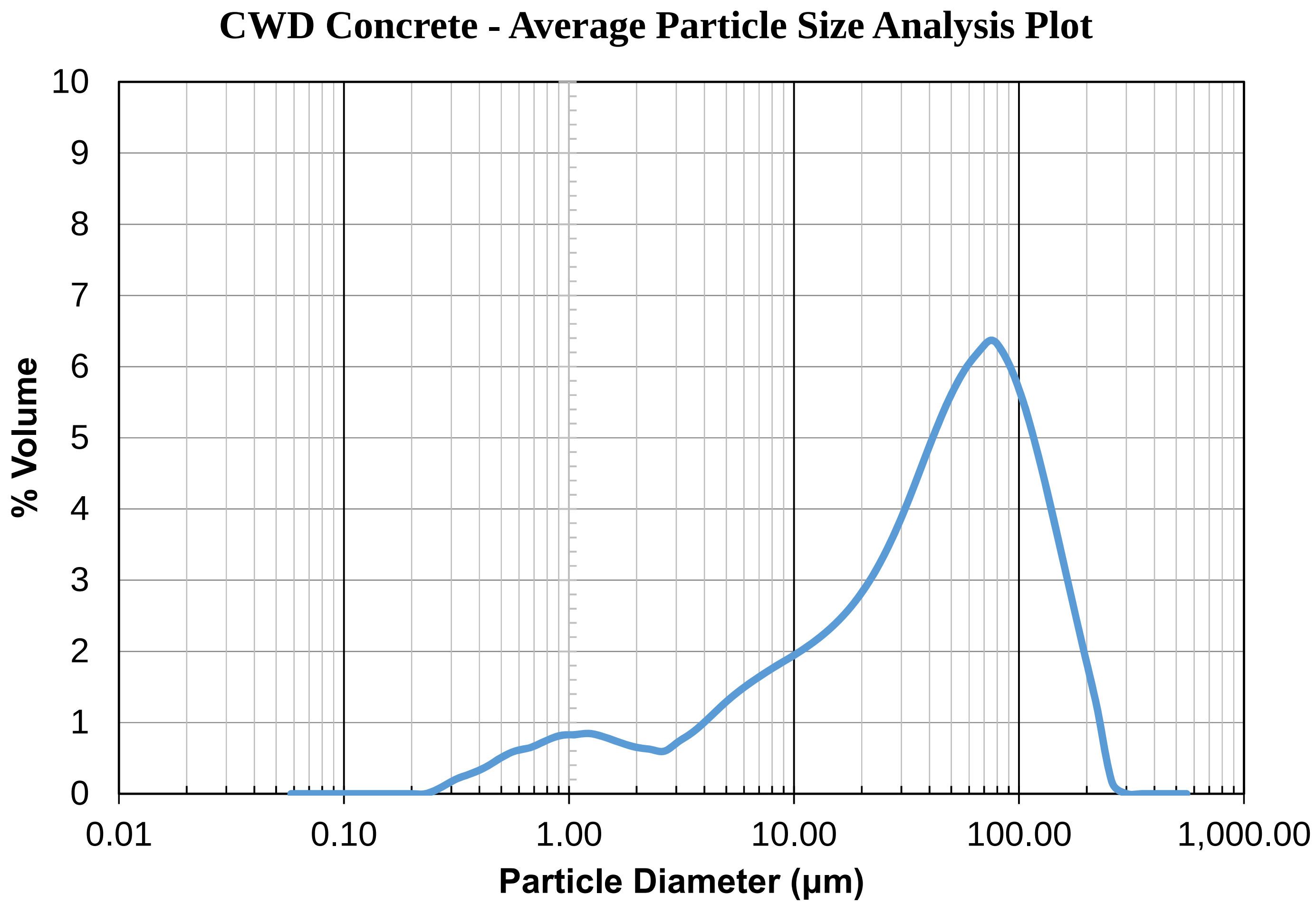

Figure 2. Average particle size analysis for CWD concrete material.

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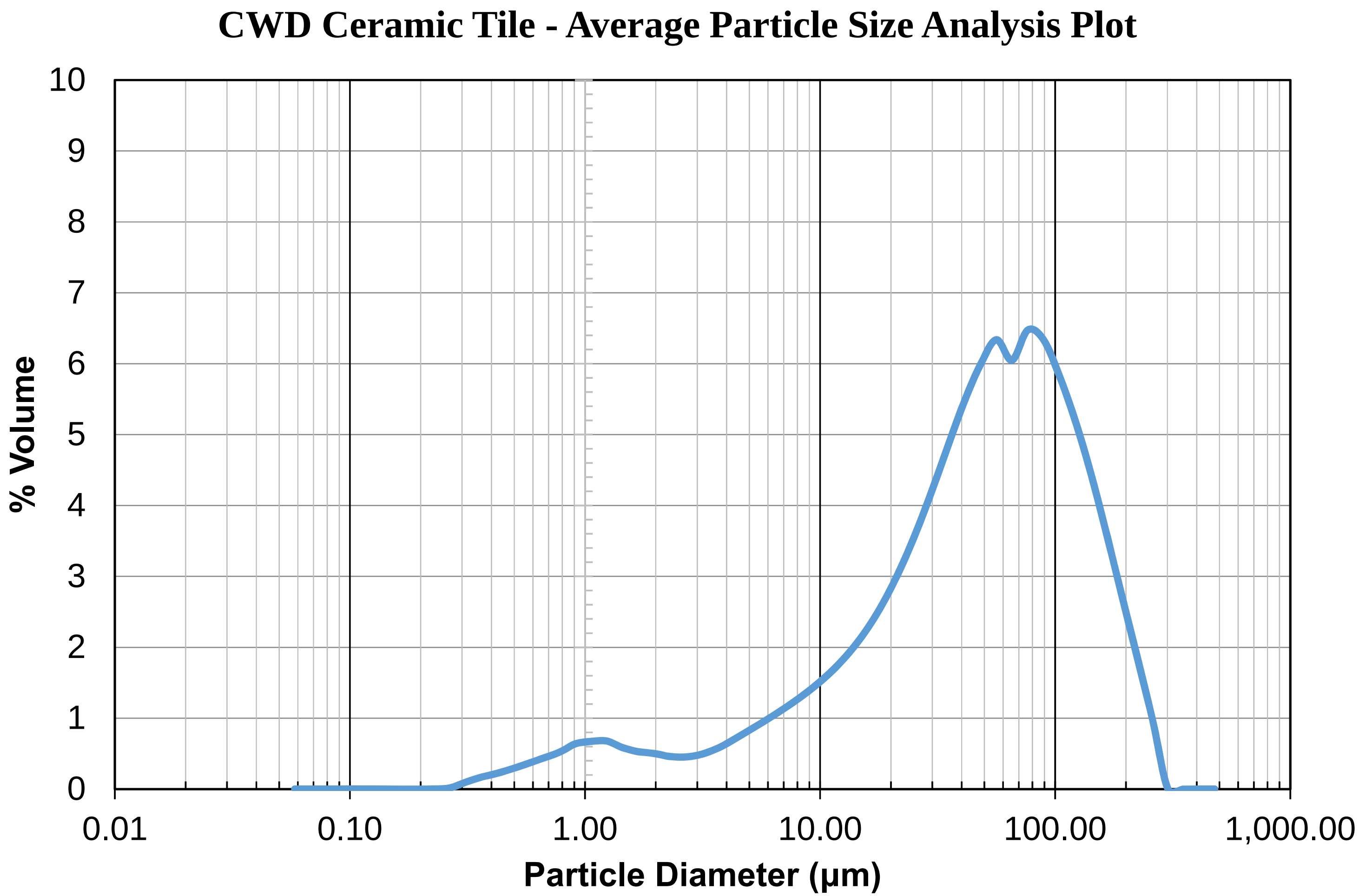

Figure 3. Average particle size analysis for CDW ceramic tile material.

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2. X-RAY FLUORESCENCE (XRF) ANALYSIS

2.1. Summary and key features

- CDW brick and CDW ceramic tile materials show predominant amounts of aluminosilicates - highest amounts of silica are almost 30% for the brick samples and 33.01% for the ceramic tiles.
- Aluminium contents are towards the range of approximately 9-9.5% as an average.
- The CDW concrete predominantly contains calcium silicates (up to 22.73% for calcium in some samples and 19.3% for silicon) with a notable variability in silicon contents.
- The concrete material contains notable variations in CaO contents, with the highest oxide concentration reaching up to 31% and the lowest being down to 15% in specific samples.

Results of XRF analysis are shown in Figures 4 to 6 and in **Error! Reference source not found.**.

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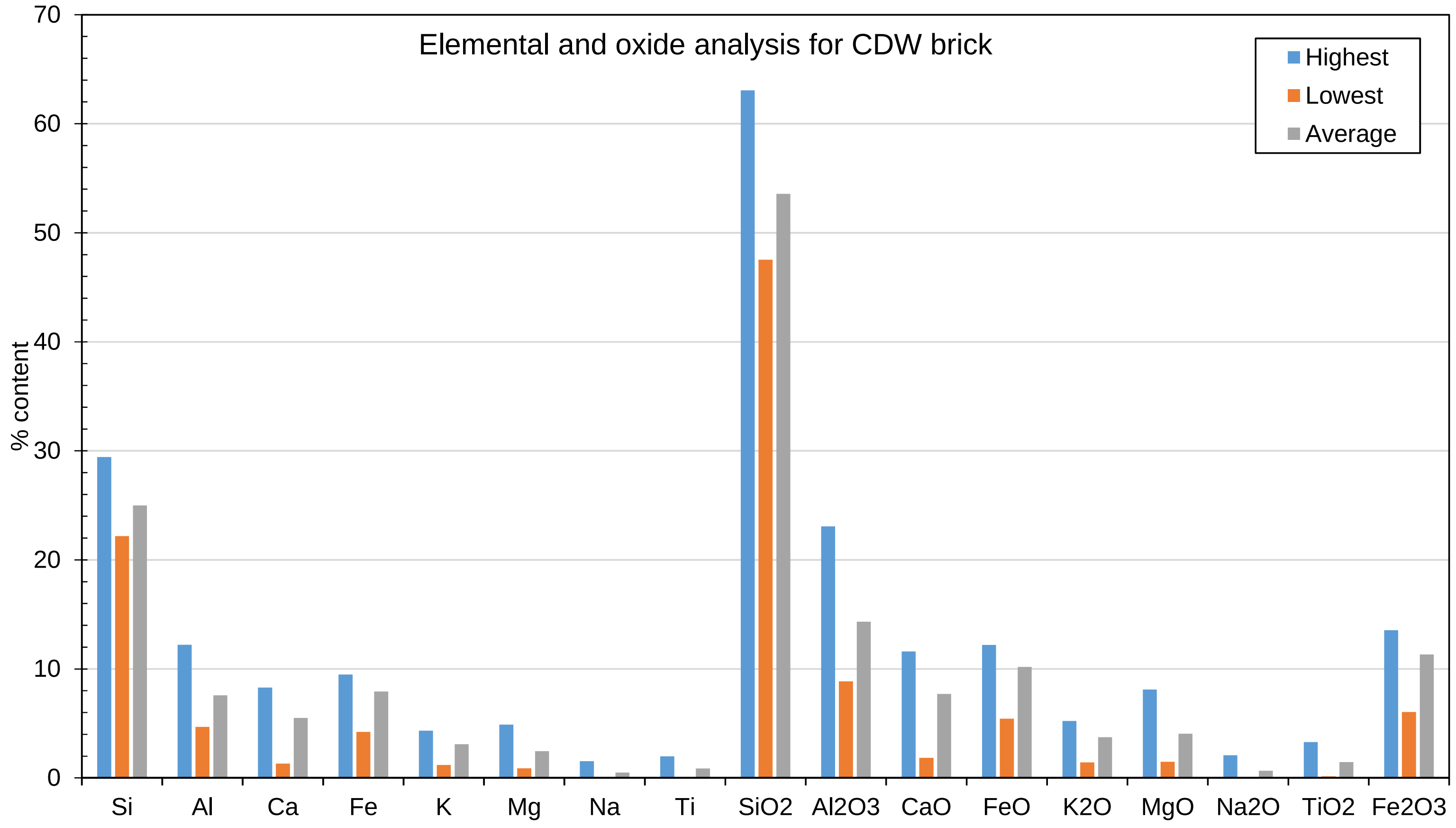

Figure 4. Summary of elemental and oxide analysis for CDW brick.

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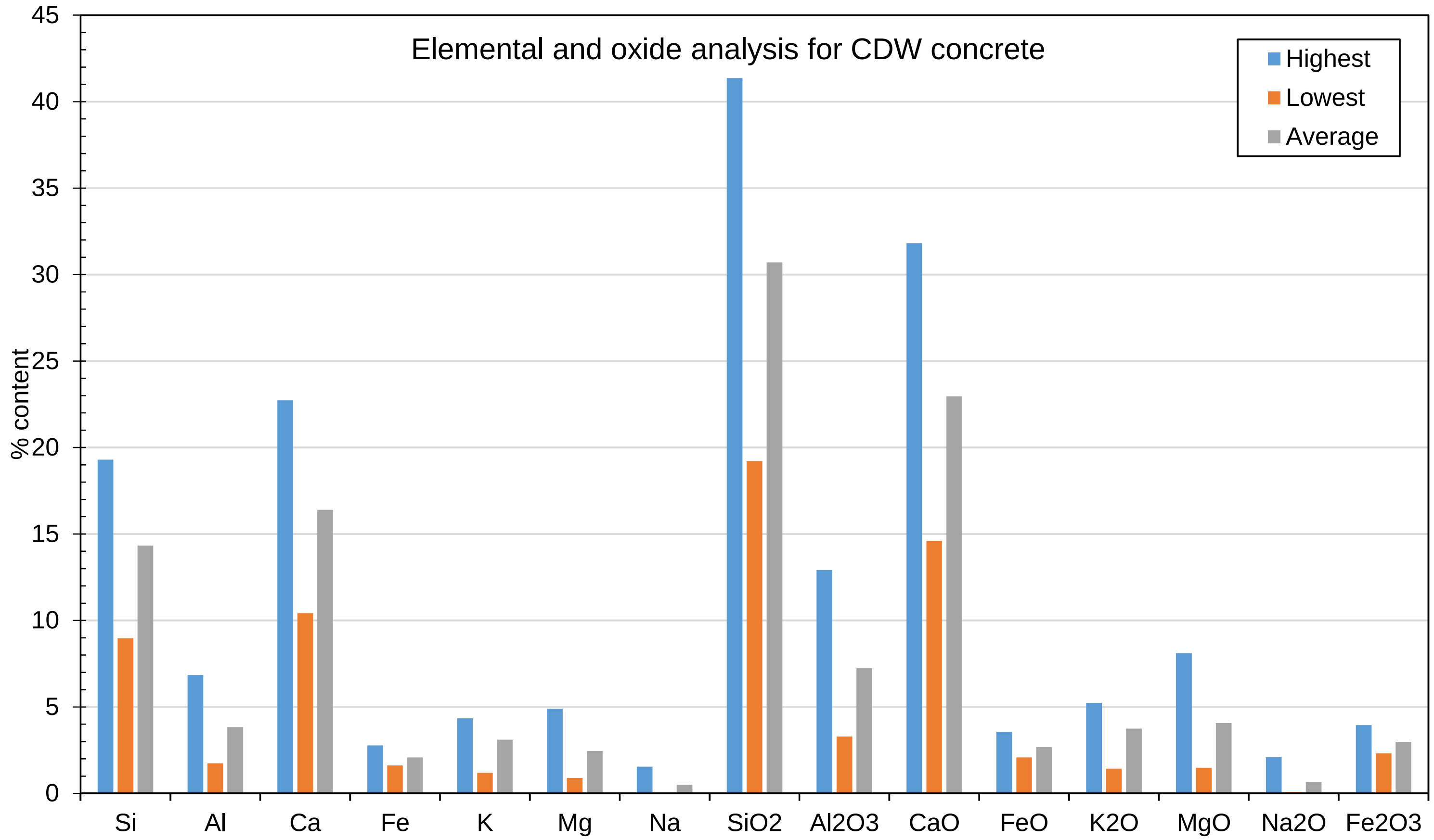

Figure 5. Summary of elemental and oxide analysis for CDW concrete.

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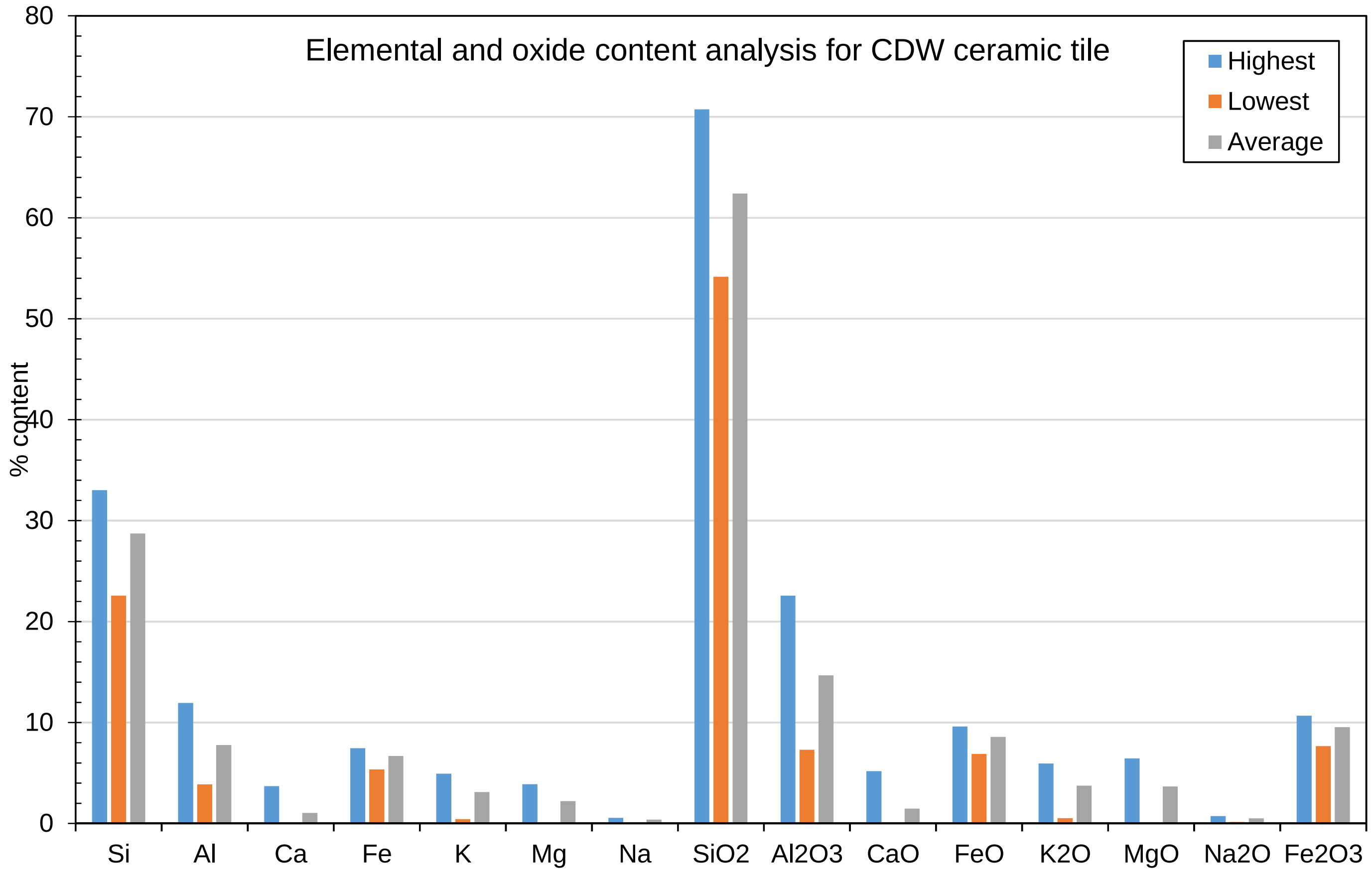

Figure 6. Summary of elemental and oxide analysis for CDW ceramic tile.

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Table 1. Summary of elemental and oxide content analysis for the 3 CDW materials

Element	BRICK				CONCRETE				CERAMIC TILE			
	Highest %	Lowest %	δ max %	Average %	Highest %	Lowest %	δ max %	Average %	Highest %	Lowest %	δ max %	Average %
Si	29.43	22.18	7.25	25.00	19.30	8.97	10.33	14.33	33.01	22.57	10.44	28.73
Al	12.21	4.69	7.52	7.59	6.84	1.74	5.10	3.83	11.95	3.87	8.08	7.77
Ca	8.29	1.32	6.97	5.51	22.73	10.43	12.30	16.40	3.70	0.04	3.66	1.05
Fe	9.49	4.23	5.26	7.92	2.77	1.62	1.15	2.08	7.47	5.37	2.10	6.68
K	4.34	1.19	3.15	3.10	4.34	1.19	3.15	3.10	4.94	0.44	4.50	3.12
Mg	4.89	0.89	4.00	2.45	4.89	0.89	4.00	2.45	3.89	0.02	3.87	2.22
Na	1.55	0.06	1.49	0.49	1.55	0.06	1.49	0.49	0.56	0.11	0.45	0.39
Ti	1.98	0.09	1.89	0.87	-	-	-	-	-	-	-	-
SiO_2	63.06	47.53	15.53	53.57	41.36	19.22	22.14	30.71	70.74	54.16	16.58	62.40
Al_2O_3	23.07	8.86	14.21	14.33	12.92	3.29	9.63	7.24	22.57	7.30	15.27	14.68
CaO	11.60	1.85	9.75	7.71	31.82	14.60	17.22	22.96	5.18	0.06	5.12	1.48
FeO	12.20	5.44	6.76	10.19	3.56	2.08	1.48	2.68	9.60	6.90	2.70	8.58
K2O	5.23	1.43	3.80	3.74	5.23	1.43	3.80	3.74	5.95	0.53	5.42	3.76
MgO	8.11	1.48	6.63	4.07	8.11	1.48	6.63	4.07	6.45	0.03	6.42	3.68
Na_2O	2.09	0.08	2.01	0.66	2.09	0.08	2.01	0.66	0.75	0.15	0.60	0.52
TiO_2	3.30	0.16	3.14	1.46	-	-	-	-	-	-	-	-
Fe_2O_3	13.55	6.05	7.50	11.32	3.95	2.31	1.64	2.98	10.67	7.67	3.00	9.54

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Ταμείο Περιφερειακής Ανάπτυξης
Κυπριακή Δημοκρατία
Διαρθρωτικά Ταμεία της Ευρωπαϊκής Ένωσης στην Κύπρο
RESEARCH & INNOVATION FOUNDATION
2016-2020 RESTART RESEARCH

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3. X-RAY DIFFRACTION (XRD) ANALYSIS

3.1. Summary and key features

The XRD results for each of the 3 CDW materials are shown in Figures 7 to 9.

- Brick waste and ceramic tiles are characterized by strong quartz and albite phases and aluminium silicates that contain salts.
- Both materials also contain ferrite-based phases, such as hematite (Fe_2O_3) of different intensities.
- Concrete CDW sample contains calcium sulfoferrites, calcium carbonates and to a lesser intensity calcium hydroxide, ettringite, calcium silicates (possibly anhydrous) and calcium aluminosilicates.

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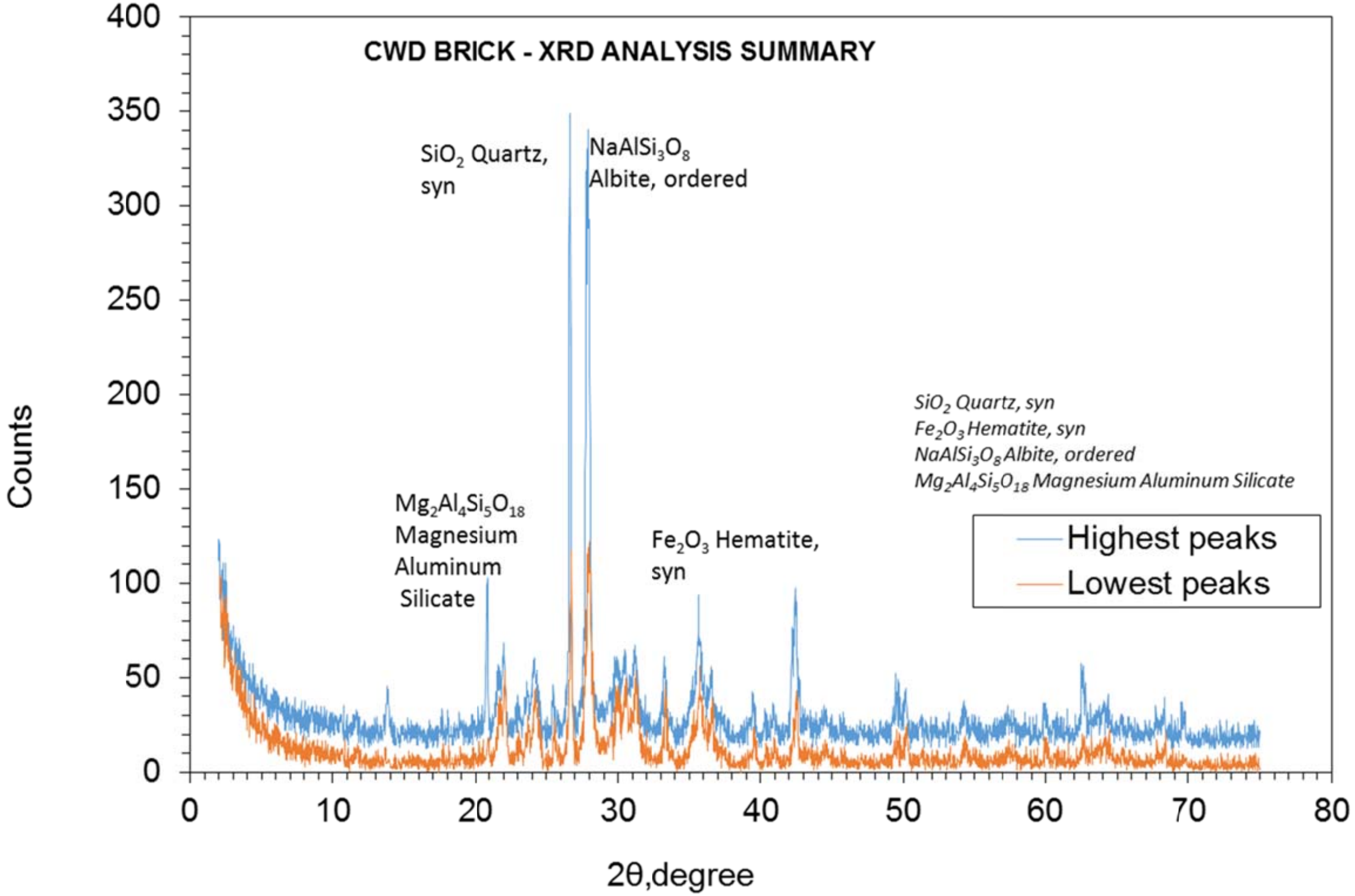

Figure 7. XRD analysis summary for CDW brick.

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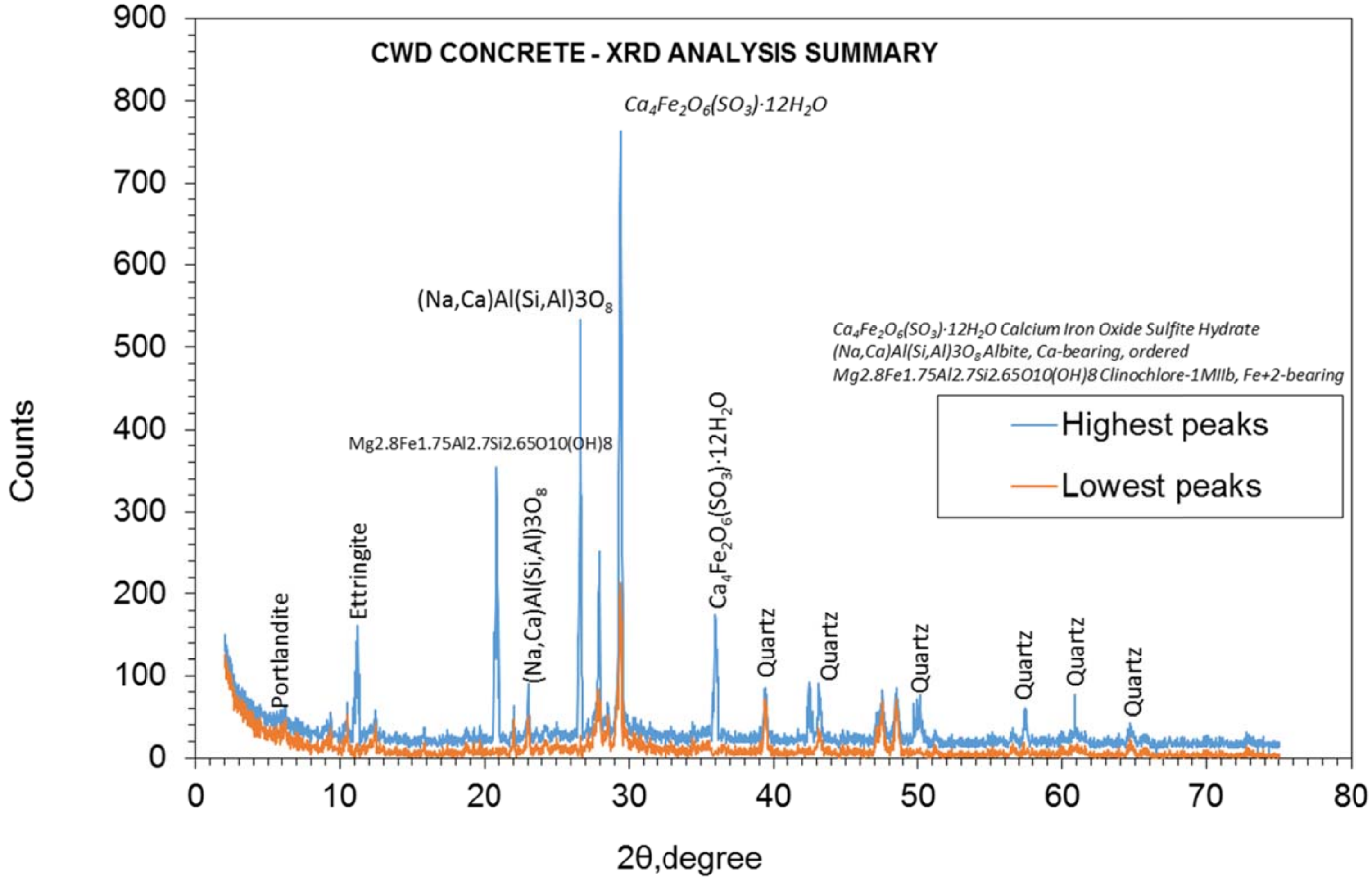

Figure 8. XRD analysis summary for CDW concrete.

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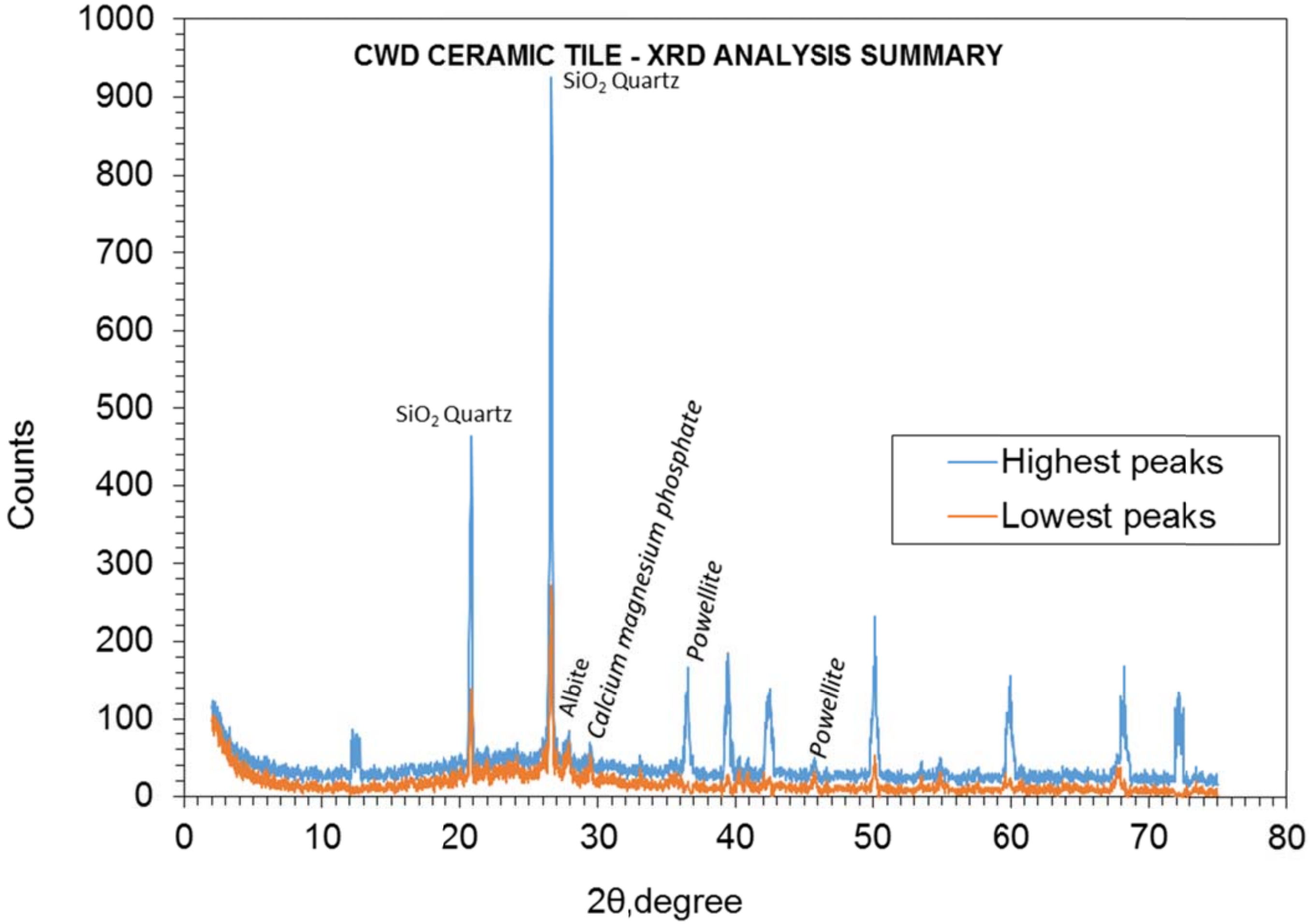

Figure 9. XRD analysis summary for CDW ceramic tile.

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4. DENSITY AND PARTICLE SIZE DISTRIBUTION

4.1. Summary and key features

The ground waste bricks, waste tiles and waste concrete were separately sieved as per CYS EN993-2:2020 and CYS EN 12948-2010. Figure 10 shows the particle size distributions of the raw materials. Table 2 and Figure 11show the results of the density determinations for the raw materials.

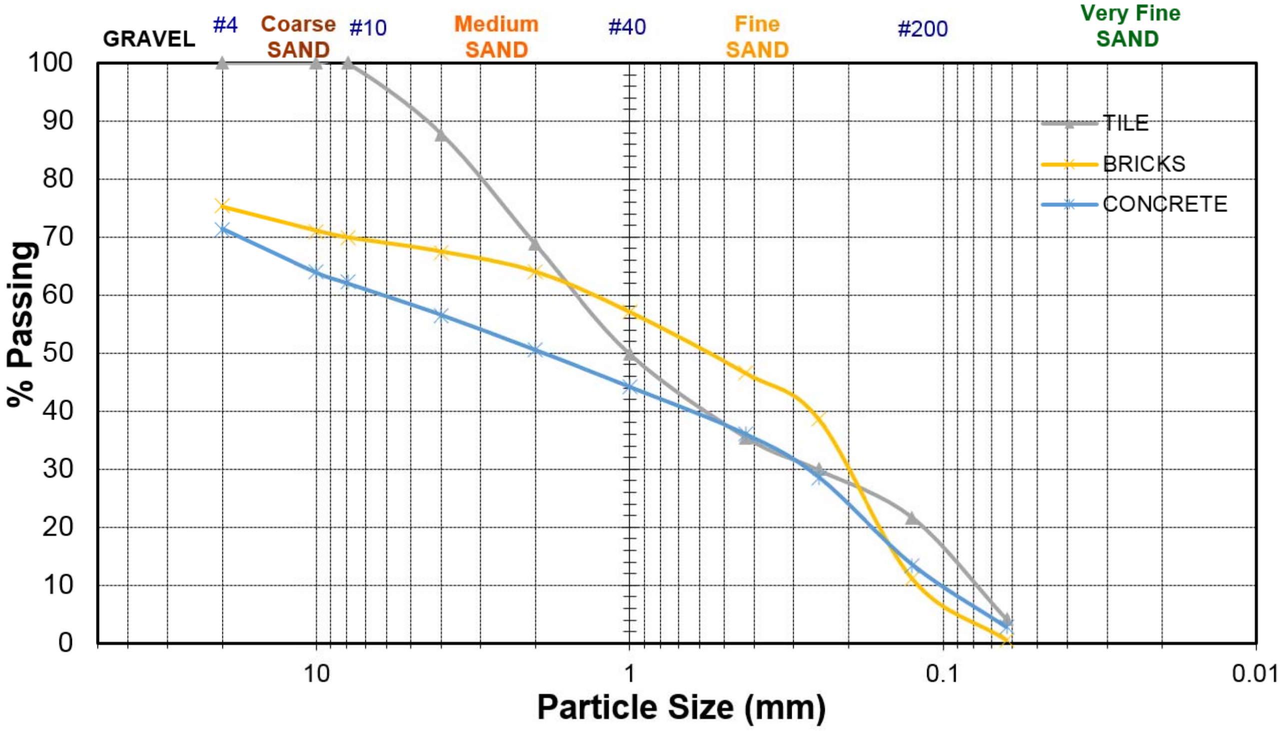

Figure 10. Particle size distribution of the raw materials.

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Table 2. Densities and water absorption values of the raw materials.

Categories	Raw Material		
	Tiles	**Bricks**	**Concrete**
Bulk density in g/cm^3	1.82	1.63	1.87
Apparent density in g/cm^3	2.56	2.81	2.68
Water absorption in %	15.77	25.57	15.98

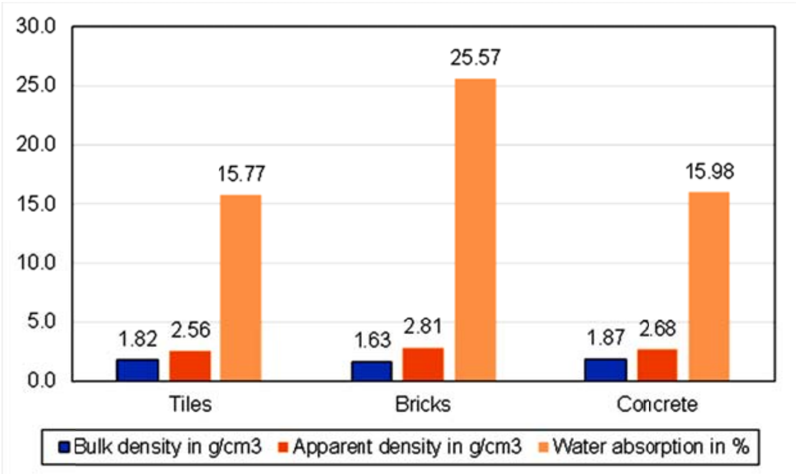

Figure 11. Summary of density determinations and water absorption values of CDW.

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5. DISSOLUTION

5.1. Summary and key features

Dissolution tests were conducted on the basis of assessing the reactivity of waste bricks and tiles. Reactivity is defined as the concentration of leached out soluble elements (Si, Al, S) following a specific time frame. The test, therefore provided the basis for establishing and developing inorganic polymer formulations incorporating solids with alkaline solutions for the subsequent experimental phase. The leaching reagents used were either NaOH or KOH at molarities of 4M and 10M.

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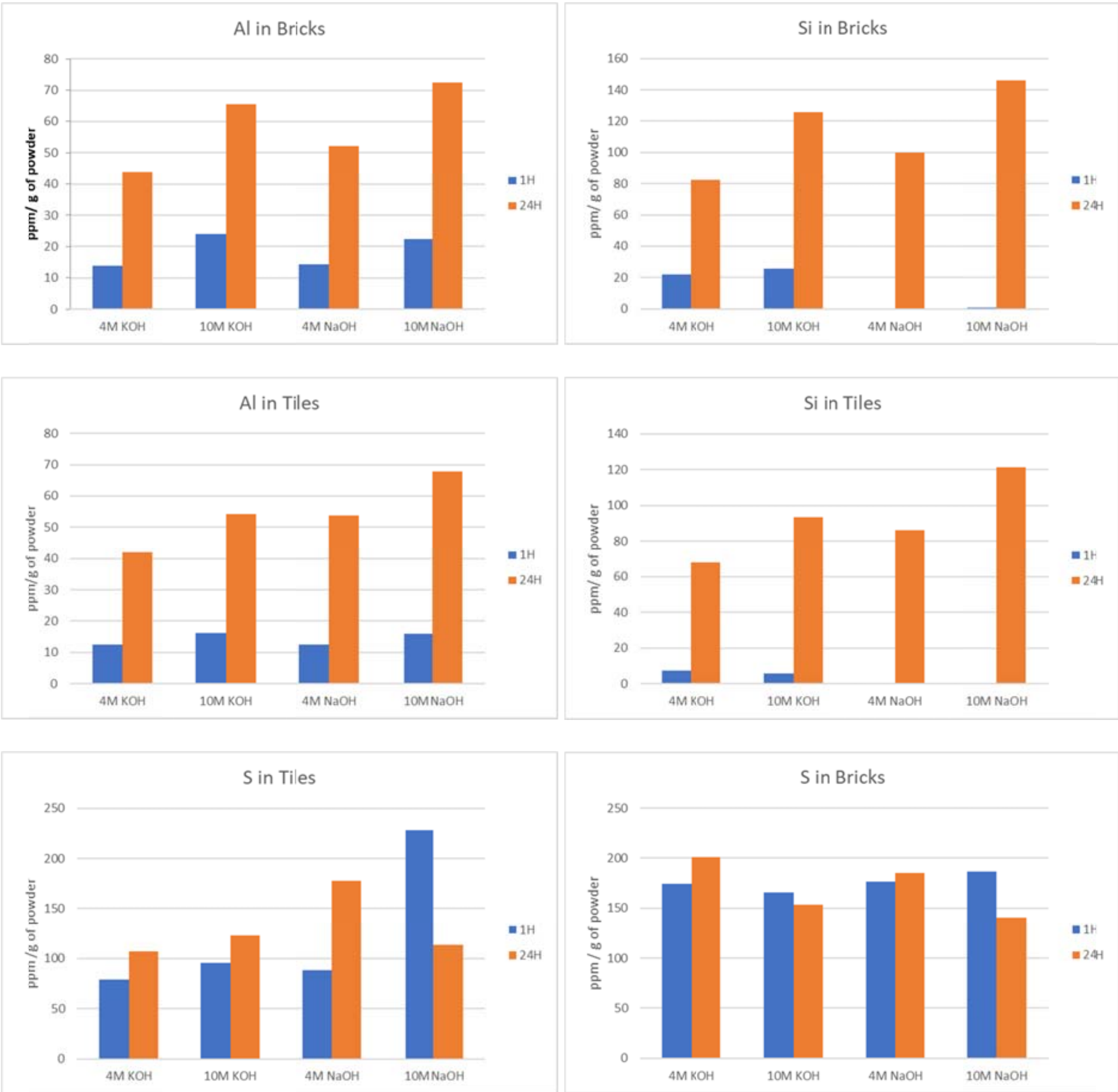

Figure 12. Dissolution of Al, Si and S from tiles and bricks in NaOH and KOH based solutions.

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6. CONCLUSIONS

The general objective of the DEFEAT project is the strategic separation and transformation of Construction and Demolition Wastes (CDW) into an innovative insulation fire resistant façade. The management of CDW in Cyprus faces several challenges and appears to be underperforming, despite the fact that a comprehensive legislative framework concerning the management of CDW is in place since 2011.

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This datasheet aims to provide a comprehensive understanding of the physio-chemical and mineralogical properties of the examined materials. This document should be consulted in conjunction with D4.1 prepared by UCY in line with the outputs and deliverables of WP4.

The materials were collected from variable sources, and the source was found to be a crucial parameter affecting the variability of mineralogical and oxide compositions. Quantitative results from XRF analysis provided numerical sets of information related to the oxide contents of the materials, whereas a qualitative set of data in XRD analysis gave relative sets of peak intensities of existing crystals within the samples. Particle size analysis provided distributions of particle volumes across a range of different diameters.

As the source of each of the as-received CDW materials was unknown, it was expected that significant variations in the mineralogical compositions would occur between the runs. It is concluded that the source is the largest determinant of the main mineralogical phases in the CDW materials. Particularly the calcium, silicon and aluminium contents have been significantly varying, whereas the potassium, sodium and magnesium contents were altered to a lesser extent. A number of factors have been found to affect the differences in mineralogical compositions:

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- Difference in mix proportions within each concrete sample for achieving different design strengths in the demolished structures (such as different aggregate contents, cement contents, w/c ratios)
- Performance requirements, design life and intended purpose of concrete used in the demolished structures yielding different microstructural characteristics
- Portland cement type/class used in different demolished structures i.e. 42.5/52.5 N/R/ SR
- Existence of admixtures in several mixtures used in the structures
- Quality of each constituent used in the mixture, i.e. aggregate absorption/density/porosity values, particle size distribution, sand quality, texture surface roughness, angularity/sphericity and surface area
- Difference in ambient conditions and geographical location (temperature, humidity and weather) that vary from source to source leading to different degrees of mechanisms occurring (such as carbonation)

For the ceramic samples investigated in this deliverable, the following factors are underpinning the high variabilities observed in the mineralogical compositions:

- Different manufacturing processes of the products procured for usage in the demolished structure (temperatures in kilns, duration of heating, constituent proportions during production)
- Quality of the raw materials utilized in the plant for the manufacturing process led to elemental variations during the final formation
- Different performance-based specifications, design life, intended purpose microstructural characteristics.

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