JOURNAL OF SUSTAINABLE AND MANUFACTURING IN TRANSPORTATION VOL. 3 NO. 1 (2023) 40-46

© Universiti Tun Hussein Onn Malaysia Publisher's Office

JSMT

http://publisher.uthm.edu.my/ojs/index.php/jsmt

e-ISSN : 2821-2835

Journal of Sustainable and Manufacturing in Transportation

Characteristics and Preliminary Study of Ceramic Concretes

Farhany Izzaty Ab Hadi[1], Noradila Abdul Latif[1*], Sharifah Adzila Syed Abu Bakar[2], Farah Nur Dini Ahmad Sha'rainon[1], Muhammad Syafiq Abdul Malik[3]

[1]Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja 86400, Johor, MALAYSIA

[2]Department of Manufacturing Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja 86400, Johor, MALAYSIA

[3]MMC Engineering Sdn Bhd, Level 23, Wisma Zelan, No. 1 Jalan Tasik Permaisuri 2, Bandar Tun Razak, Cheras 56000, Kuala Lumpur, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jsmt.2023.03.01.005
Received 17 May 2023; Accepted 6 June 2023; Available online 31 July 2023

Abstract: One of the most adaptable and frequently used building materials in the world is concrete. It is flexible in terms of size and shape, sturdy, long-lasting, low-maintenance, fireproof, and easy to use. However, further research is needed to increase the durability and sustainability of this material since concrete technology is still in developing industry. Therefore, it's crucial to comprehend how microstructure and characteristics interact in terms of how they affect concrete's strength, dimensional stability, and durability. The findings of this research are crucial in identifying the properties and characteristics of the ceramic concrete used for bridge construction or others. Advanced research to ascertain the hardness and physical qualities and features of ceramic concrete material is required. Thus, it will help to produce a reliable data for engineer to refer for their future works or project. To ascertain its hardness and physical characteristics, research has been conducted on ceramic concrete for several types of grades. In the current study, the ceramic concrete was tested through the physical and Vickers-hardness tests. The X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) on samples were performed to observe the phases and morphology of the ceramic concrete, respectively. For results of physical testing, the density and water absorption correlate to each other by the denser of the sample, the lower of water absorption and the porosity level of the ceramic concrete. Based on the Vickers micro hardness test, it can be seen that longer curing days affected the hardness, where the concretes of grade 30 and 40 at 28 curing days had better hardness value. Next, Scanning Electron Microscopy (SEM) on samples shown almost same microstructure, while the dominant phase of all ceramic concrete grades was SiO_2 by the XRD analysis. In summary, better properties of ceramic concretes were indicated at 28 curing days for both grades of ceramic concretes.

Keywords: Ceramic concrete, characteristics, physical test, SEM, XRD, density, porosity, Vickers hardness

1. Introduction

Concrete is known as a strong material, durable, low maintenance, fireproof, easy to use and able to customize for any size or shape. Concrete consists of four main components: water, cement, sand (fine aggregate) and gravel (coarse aggregate). However, concrete technology is still growing research field, and needed to improve the durability and sustainability of this material. Hence, it is crucial to understand the relationships between microstructure and properties in terms of their influence on the strength, dimensional stability and durability of concrete.

**Corresponding author: noradila@uthm.edu.my*
2023 UTHM Publisher. All rights reserved.

From the previous researches, Szlachetka et. al. (2021) were summarized that a suitable curing method improved the degree of hydration, where the relation of hydration increased the strength of concrete. From the study of compressive strength and shrinkage for different types of curing conditions, it found that the increase of compressive strength was decreased the shrinkage deformation. It also indicates that appropriate curing days during concrete maturation was delayed the shrinkage movement even cannot be eliminated them totally [1]. Next, Maheshkumar (2014) was investigated the compressive strength and density of lightweight foamed concrete (LFC). The compressive strength and density of LPC was increased at increasing the age days. Curing is essential to conventional concrete, where the cement-based elements need moisture for hydration at an early age [2]. Ahmad et. al., (2021) were reported the compressive strength of all different percents of mixed nylon fiber increased at increasing the curing days for nylon fiber reinforced self-compacting concretes [3]. Based on the industry, MMC Engineering Sdn. Bhd. is generally conducted the compression test for the cube test samples to confirm the strength of each grade and curing days of concretes. Thus, addition study on the characteristic and hardness of ceramic concrete at different grades and curing days was focus in the current study. From the research outcome, the reliable properties will help engineers to refer for their future work and project.

2. Materials and Methods

2.1 Ceramic Concrete

Four types of cube test concrete sample were supplied by the MMC Engineering Sdn. Bhd. There were concretes of Grade 30 and grade 40 with each grade soaked in water at duration days of 7 and 28 curing days. The XRF analysis of these concretes is shown in Table 1. It shows that the SiO_2 is the main element in concretes.

Table 1 - Element composition for concretes

G30 7D	Compound	SiO_2	CaO	Al_2O_3	Fe_2O_3	K_2O	SO_3	MgO	TiO_2	Others
	Concentration Unit (%)	42.973	34.190	11.239	3.590	2.617	1.866	1.830	0.512	0.327
G30 28D	Compound	SiO_2	CaO	Al_2O_3	K_2O	Fe_2O_3	MgO	SO_3	P_2O_5	Others
	Concentration Unit (%)	60.369	17.633	12.085	3.914	2.474	1.122	0.609	1.122	0.825
G40 7D	Compound	SiO_2	CaO	Al_2O_3	K_2O	SO_3	MgO	P_2O_5	TiO_2	Others
	Concentration Unit (%)	46.618	33.435	7.975	2.034	2.617	0.552	0.444	0.335	0.181
G40 28D	Compound	SiO_2	CaO	Al_2O_3	Fe_2O_3	K_2O	SO_3	MgO	P_2O_5	Others
	Concentration Unit (%)	48.494	29.466	11.050	3.343	3.220	1.537	1.355	0.568	0.796

2.2 Preparation of Sample

The small pieces of cube test concrete sample were crushed to be fine particles using the rotary ball mill. The fine concrete particles were then sieved at sieve wire mesh of 63 µm using the vibrating sieve shaker machine. The finer concrete particles were weighed and mixed with binder of zinc stearate at 1 wt.%. The sample was compressed using the uniaxial hydraulic press machine up to 9 tones. Sample was sized at diameter and height of 1 cm and 1 cm, respectively. Sintering process was conducted up to 1000 °C for all ceramic concrete samples where, the sintering profile was referred from the Jamil, N.H et. al. (2021) [4].

2.3 Physical Test, Vickers Microhardness Test, XRD and Morphology Test

The density test was conducted by referring to the standard ASTM C20-00 [5] for determining the physical properties such as water absorption, porosity and density of ceramic concretes. At beginning, ceramic concrete samples were weighted using the Mettler Toledo. Next, the samples were boiled in distilled water for three hours, then the samples were rested for twelve hours. Vickers Microhardness test has been performed for 8 times indentions with a load of 9.807 N. X-Ray Diffraction Test was carried to identify the phases that existed in ceramic concretes. Morphology test of Scanning Electron Microscopy was conducted to observe the microstructure of ceramics concretes.

3. Results and Discussion

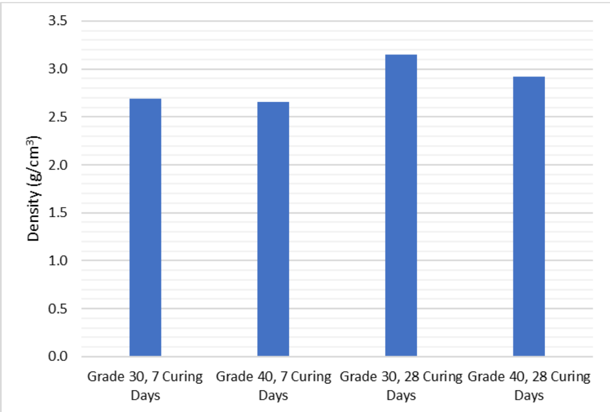
3.1 Physical Properties of Ceramic Concretes

Physical testing was performed to determine the relationship between the ceramic concretes' density, apparent porosity and water absorption. The physical test results for all the ceramic concrete samples are shown in Table 2. Figure 1 shows the physical properties for both grades of ceramic concrete after 7 and after 28 of curing days.

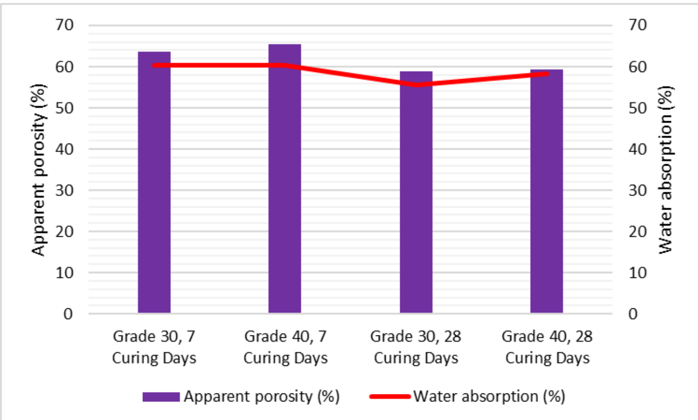
Table 2 - Physical properties of ceramic concretes

Samples	Density (g/cm^3)	Apparent porosity (%)	Water absorption (%)
Grade 30, 7 Curing Days	2.69	63.7	60.3
Grade 40, 7 Curing Days	2.66	65.4	60.4
Grade 30, 28 Curing Days	3.15	58.8	55.6
Grade 40, 28 Curing Days	2.92	59.4	58.3

The density of the sample plays a major role to the physical properties of the ceramic concrete sample. Technically, if one sample has higher density, the porosity and water absorption will be lower. High density concrete generally has good in strength and less voids and porosity. Concrete becomes less permeable to water and soluble substances as the pores in it decrease. In Figure 1, both ceramic concretes of 28 curing days indicate slightly higher density, while lower porosity and water absorption than that of the ceramic concretes of 7 curing days. Based on the previous study, concrete density is optimised to increase structural effectiveness (the strength to density ratio), minimise transportation costs, and improve hydration by substituting a portion of the normal-density aggregates (regarding to coarse aggregate, fine aggregate or both) with similar composition of low-density aggregate [6]. Generally, the void has an influence on the strength of the sample. Based on Hilal. at. el. (2015), higher foam volume caused more void merging, resulting in huge irregular voids with a widespread spread of void sizes and lower strength [7].



(a)



(b)

Fig. 1 - Physical properties of (a) density; (b) water absorption and apparent porosity of ceramic concretes

Jouni (1995) had reported the prewetting or impregnating of the lightweight aggregate was the most efficient approach to limit or avoid aggregate absorption in concrete. A reasonably extended immersing in water or a vacuum treatment are required to achieve a sufficient degree of saturation. Then, remixing new concrete by adding a dosage of superplasticizer was an effective and widely used approach for reducing the issues caused by water absorption. At construction site, the concrete was stirred, and a supplementary dose of superplasticizer may be applied. The applicability of such a process was determined by the application and local conditions [8].

3.2 Mechanical Properties of Ceramic Concretes

Table 3 list the mechanical properties of ceramic concretes i.e., Vickers hardness and compression strength that obtained from the MMC Engineering Sdn. Bhd. Figure 2 shows the trends of Vickers hardness and compression strength at different types of grades and curing days on ceramic concretes.

Table 3 - Mechanical properties of ceramic concretes

Samples	Average Hardness (HV)	Compression strength from the MMC Engineering (MPa)
Grade 30, 7 Curing Days	48	28.17
Grade 40, 7 Curing Days	41	25.64
Grade 30, 28 Curing Days	64	39.3
Grade 40, 28 Curing Days	62	44.5

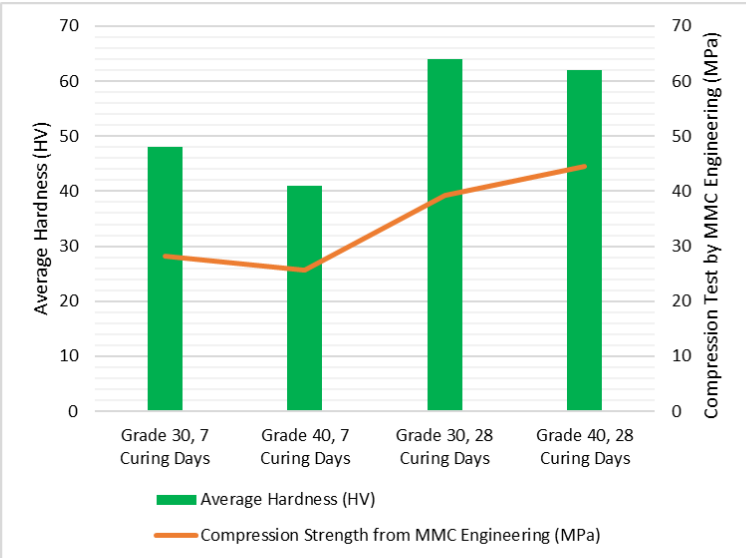


Fig. 2 - Vickers hardness and compression strength of ceramic concretes

Figure 2 shows the both ceramic concretes of 28 curing days indicate higher hardness and compression strength compared to the ceramic concretes of 7 curing days. Curing has a significant effect to the strength and durability of concrete. However, curing time is also dependent to all these factors, for instance, specified strength of concrete, moisture proportions, size and shape of concrete member and temperature condition. Commonly, curing occurs instantly based on the placement and finishing of concrete and require to maintain the ideal moisture and temperature condition, both at depth and on the surface, for extended time duration. A well cured concrete has a suitable level of moisture to permit for ongoing hydration and the strength development, volume, freezing stability and thawing resistance, as well as abrasion and scaling resistance [9]. Based on He. J. et. al., (2018), the curing time was a major component influencing the development of strength of concrete, and then the constant temperature was the primary period of development of concrete strength [10].

3.3 XRD Analysis

Figure 3 shows the XRD analyses of ceramic concretes of Grade 30 and 40 for 7 and 28 curing days. Based on the XRD graph analyses of both grades and curing days, these indicated that the dominant element in ceramic concretes was SiO_2. From the previous study, Uysal et. al. (2022) reported that filler materials of brick, ceramic, glass powders as well as recycled aggregate were contained of SiO_2 with range of 69.42 to 55.5 wt%, and the dominant phase of the recycle concrete was SiO_2 by the XRD analysis [11].

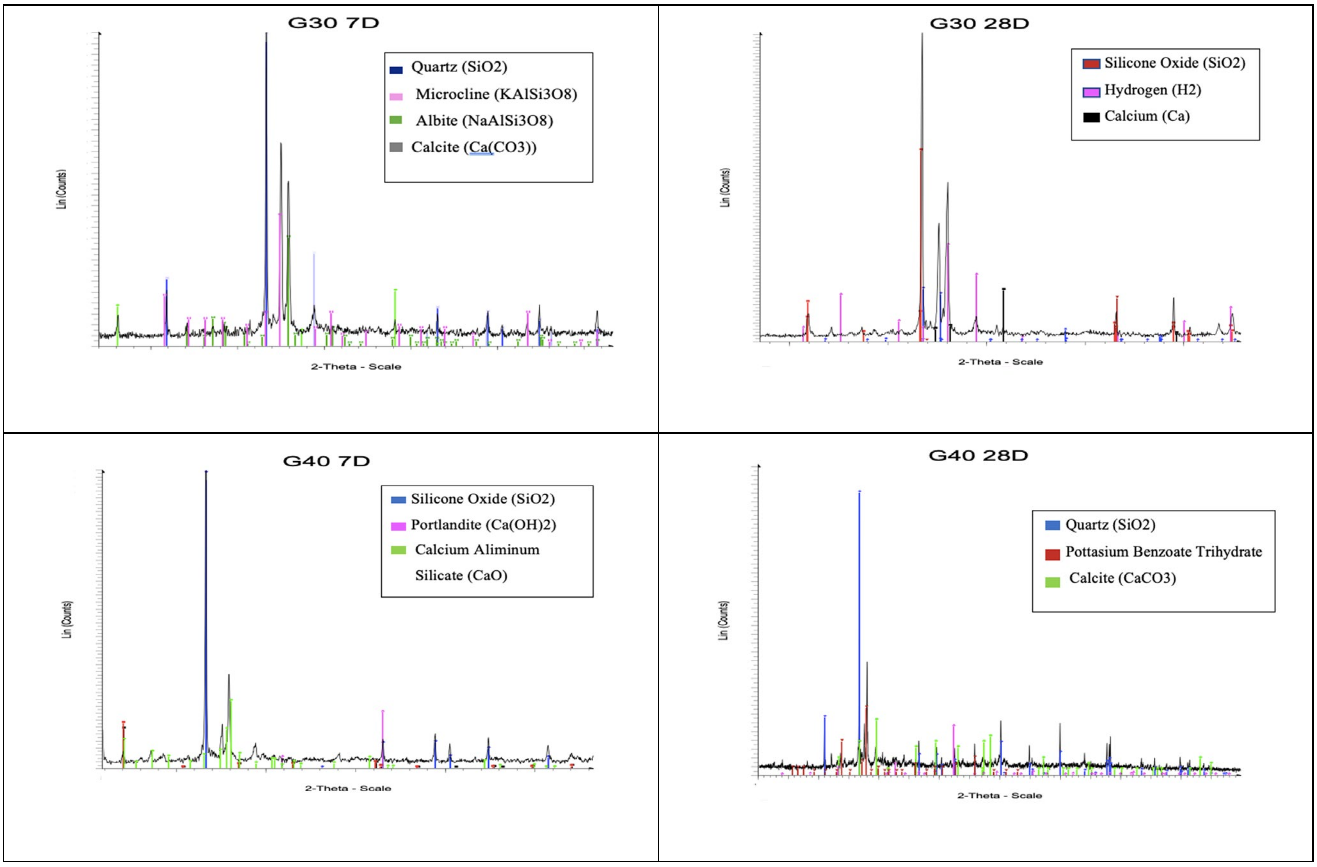
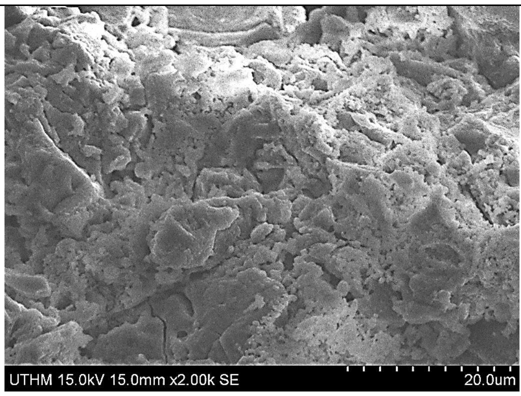
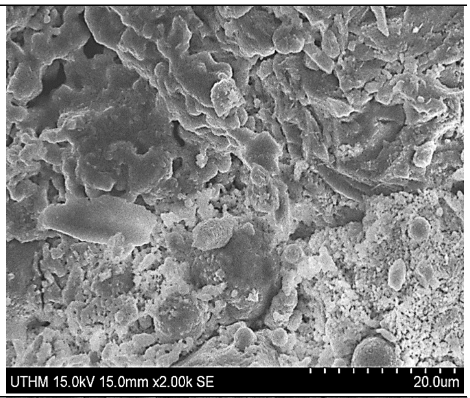
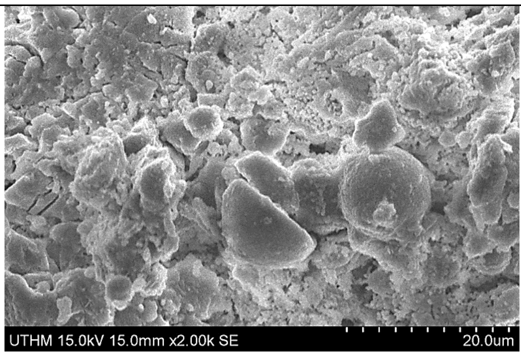
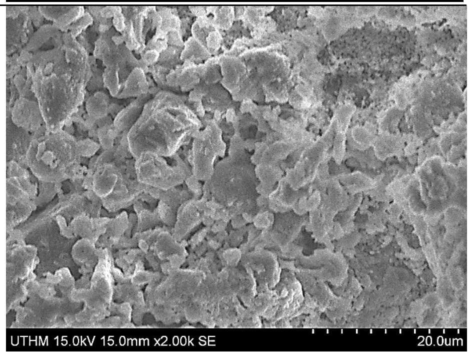


Fig. 3 - XRD analyses for the (a) Grade 30, 7 curing days; (b) Grade 30, 28 curing days; (c) Grade 40, 7; (d) Grade, 28 Days

3.4 Morphology by Scanning Electron Microscopy (SEM)

Microstructure of ceramic concretes were captured using the Scanning Electron Microscopy as shown in Table 4. It was observed that the particles of both grades at 7 and 28 curing days are in irregular shapes. Also, it was shown almost similar microstructure for all types of ceramic concrete. It was indicated that the microstructure of all grades was independently to these curing days.

Table 4 - Microstructure of ceramic concretes

Curing Days	Grade 30	Grade 40
7		
28		

From Adithiya (2017), the production and distribution of hydration products in hydrated cement paste were investigated in different mix amounts. The microstructure of the different mixes was investigated and compared to that of the nominal mix. Based on the hydration products generated after 28 days, the microstructure and strength attributes were connected. The development of hydration products in the microstructure of concrete mixes was used to analyze and explain the cause for the strength of the concrete [12].

4. Conclusion

1. Physical properties of density and water absorption were correlated to each other, where denser concrete resulted lower of water absorption and porosity of the ceramic concretes.
2. Vickers micro hardness was dependent to the period of curing days. It found that the hardness of both grades increased at 28 curing days. This results also similar to the compression strength of concretes that obtained by industry, where at the 28 curing days indicates high strength of concrete than that of the 7 curing days.
3. The dominant phase of ceramic concretes was SiO_2, where traced by the XRF and XRD analyses.
4. Observation by using the SEM was captured that the microstructures in irregular shapes and shown almost similar pattern for all types of ceramic concretes.

Acknowledgement

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through GPPS (vot Q215). We also want to thank the MMC Engineering Sdn. Bhd. for sponsoring the materials and knowledge.

References

[1] Szlachetka, O., Witkowska-Dobrev, J., Dohojda, M., & Cała, A. (2021). Influence of compressive strength and maturity conditions on shrinkage of ordinary concrete. *Advances in Mechanical Engineering*, 13(6) Retrieved June 8, 2021 from https://doi.org/10.1177/16878140211024434

[2] Maheshkumar H. Thakrele (2014) Experimental Study on Foam Concrete. *International Journal of Civil, Structural, Environ-mental and Infrastructure Engineering Research and Develop-ment*, 4(1), pp.145-158.

[3] Ahmad, J., Zaid, O., Aslam, F., Martínez-García, R., Alharthi, Y. M., Hechmi EI Ouni, M., Tufail, R. F., & Sharaky, I. A. (2021). Mechanical properties and durability assessment of nylon fiber reinforced self-compacting concrete. *Journal of Engineered Fibers and Fabrics*. Retrieved December 23, 2021 from https://doi.org/10.1177/15589250211062833
[4] Jamil, N.H., Abdullah, M. M.A.B., Pa, F.C., Mohamad, H., Ibrahim, W.M.A.W., Amonpattaratkit, P., Gondro, J., Sochacki, W. & Ibrahim, N. (2021) Self-Fluxing Mechanism in Geopolymerization for Low-Sintering Temperature of Ceramic. *Materials*, 14, pp. 1325.
[5] ASTM C20-00 Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water.
[6] George C. Hoff, (2002). "Guide for the Use of Low-Density Concrete in Civil Works Projects", Innovation for Navigation Projects Research Program, U.S. Army Corps of Engineers Washington, DC.
[7] Hilal, A. A., Thom, N. H., & Dawson, A. R. (2015). On void structure and strength of foamed concrete made without/with additives. *Construction and Building Materials*, 85, pp. 157-164. Retrieved June 15, 2015 from https://doi.org/10.1016/j.conbuildmat.2015.03.093.
[8] Jouni P. (1995) *Effect of water absorption by the aggregate on properties of high-strength lightweight concrete*. Norges Teknisk-Naturvitenskapelige Universitet, Trondheim, Norway: Master Thesis. ,https://www.osti.gov/etdeweb/servlets/purl/515676
[9] Zemajtis, J.Z. (2014) Role of Concrete Curing. Portland Cement Association, Skokie.
[10] He, J., Ma, K., Long, G., & Xie, Y. (2018). Mechanical properties evolution of concrete in steam-curing process. *J Chinese Ceram Soc*, 46(11), pp.1584-1592.
[11] Mucteba Uysal, Yurdakul Aygörmez, Orhan Canpolat, Turgay Cosgun, Ömer Faruk Kuranlı (2022), Investigation of using waste marble powder, brick powder, ceramic powder, glass powder, and rice husk ash as eco-friendly aggregate in sustainable red mud-metakaolin based geopolymer composites, *Construction and Building Materials*, 361(129718), pp.1-20
[12] Adithya Saran, & Magudeswaran, P. (2017). SEM Analysis on Sustainable High Performance Concrete. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(6), pp. 10237-10246 ijirset.com. http://www.ijirset.com/upload/2017/june/16_SEM.pdf