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Effect of Partial Inclusion of Tiles and Brick Waste as Binders in SCM Elements on Fresh State and Early Age Mechanical Properties

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Abstract – The rapid change in population and urbanization across the world, especially in the last 50 years, has brought with it an increasing need for housing. The process of meeting the housing need sometimes involves the maintenance and proportioning of existing buildings, and often involves the demolition of buildings that have completed their lifespan and the construction of new ones in their place. The construction sector, which has a large volume in the economies of countries, is developing with different innovations and applications every year.

One of the most critical problems examined in the context of environment and sustainability in many academic and sectoral studies based on the construction sector is cement production, which is associated with greenhouse gas emissions, and the disposal and storage process after demolition of old buildings. In this study, the reduction of cement use and the use of ceramic and brick wastes, which are of great importance as construction demolition waste, as binders in Self-Compacting Mortar (SCM) systems were evaluated with dual and single designs. As a result of the study, the fresh state properties of brick and ceramic waste in SCM systems comply with EFNARC criteria. In addition, the early age mechanical properties are acceptable for use in structural systems.

Keywords – Self-Compacting Mortar, Brick Waste, Ceramic Waste.

I. INTRODUCTION

Rapid construction all over the world depends on cement systems based on production processes that are often not considered environmentally friendly and sustainable. This is because the production of binders and especially cement, the main component of cement systems, is based on a wide range of production processes, starting from the procurement of natural limestone stones to high temperature and grinding processes [1]. According to data on cement production, which is directly linked to natural resource consumption and GHG (greenhouse gas) emissions, 2.8 tons of raw material equals approximately 1 ton of GHG emissions. In one year, GHG emissions associated with cement production account for about 7% of all anthropogenic GHG emissions. Since cement is the most expensive component of concrete, reducing cement use is primarily an economic-based solution. On the other hand, demolition and disposal of end-of-life structures also account for large volumes in the economies of countries. The use of construction demolition waste as a substitute main component for aggregate or binder in production processes after the recycling process will create marginal benefits in the context of the sector and countries. All these reasons bring about new searches for recyclable and recycled main components in production processes, fueled by environmentalist approaches. RILEM

(Reunion Internationale Des Laboratoires D'essais Et De Recherches Sur Les Materiaux Et Les Constructions) committee has defined three types of reclaimed aggregates [2]. These are: Type 1: Primarily derived from masonry rubble Type 2: Primarily derived from concrete rubble Type 3: Derived from a mixture of natural aggregate (80%) and recycled aggregate (20%) [3]. Recycled aggregate can be of different types such as brick aggregate, glass aggregate, asphalt and bitumen aggregate, concrete aggregate, recycled tiles, and marbles from flooring, cladding and ceramic products. Aggregate typically processed by crushing old concrete through crushers, such as demolished waste concrete, is considered recycled concrete aggregate [4]. In many academic studies on the reuse of demolished or heavily damaged construction wastes after the completion of the service life of buildings or after devastating natural disasters such as earthquakes, it is common to use construction demolition wastes as aggregates in concrete, reinforced concrete, mortar and derivatives or as the main component that replaces the binder after some processes [5-7]. In addition, the usability of recycled products obtained from construction concrete demolition waste as asphalt aggregate [8] and in soil improvement methods [9] is also an important subject of new generation studies. Accordingly, the partial or complete use of construction demolition waste as aggregate increases water absorption, reduces compressive and flexural strength and decreases adhesion [10]. There are also evaluations that emphasize that the experimental results obtained in this form should be improved and developed, and that substitution methods are at an acceptable level [11].

Brick is one of the most widely used building materials in the construction industry. In addition to the production process, a large amount of brick waste is generated as construction rubble waste after demolition, making recycling inevitable. Used both as aggregate and as a binder in cement systems, brick waste is the determining factor in many engineering and durability properties of the element used due to its hollow structure. Brick waste, which exhibits a negative trend in the mechanical properties of concrete with more than 20 wt% aggregate substitution, should be ground before being used as a binder in cement systems [12].

The use of waste brick dust in self-compacting concrete elements is an important determinant of compressive strength, as well as affecting many engineering properties, and the strength loss it causes is attributed to poor adherence at the interface between the aggregate and the cement paste [13]. In addition, studies on brick waste admixed concretes have warned of reductions in flexural strength [3,14]. In addition, the use of ceramic wastes in concrete and its derivatives is generally based on substitution with aggregate in mixtures made with cement [15, 16]. However, substitution with cement used as a binder in the mix is an important research topic in terms of sustainability [17-20]. For this purpose, this experimental study investigated the effect of tile waste powder (TWP) and brick waste powder (BWP) on the fresh state and early age mechanical properties of SCM elements produced based on a single and double substitution design of cement at 2.5% - 5% band.

II. MATERIALS AND METHOD

A. *Materials*

CEM-I 42.5R Portland cement [21], crushed sand (CS) (0-4 mm), TWP, BWP, municipal water [22], polycarboxylate-based high range water reducer were used in the SCM mixtures prepared within the scope of the study. The sieve analysis of the crushed sand is given in Table 1 and the factory data on the chemical, physical and mechanical properties of the cement used are given in Table 2 [23]. The grain densities of CS, TWP, BWP are 2.6, 2.0, 1.8 gr/cm^3, respectively.

Table 1. Crushed sand sieve analysis

Sieve size (mm)	**Cumulative passing percentage (%)**
4 mm	100.00
2 mm	68.43
1 mm	44.21
0.5 mm	21.96
0.25 mm	13.53
0.125 mm	7.57
0.063 mm	0.00
Pan	0.00

Table 2. CEM-I 42.5R cement properties

Chemical composition (%)	Portland Cement
CaO	63.37
SiO_2	19.34
Al_2O_3	3.75
Fe_2O_3	4.15
MgO	3.1
SO_3	3.15
K_2O	0.81
Na_2O	0.41
Loss of ignition	1.92
Blaine (m^2/kg)	366

To provide SCM properties in accordance with EFNARC criteria, Sika Visco Crete Hi-Tech-28 polycarboxylate based high water reducer (HRWR) with product code Sika Visco Crete Hi-Tech-28 was used in the mix design in accordance with TS EN 934-2+A1 [24].

In 2023, tile and brick wastes obtained from the construction demolition waste storage areas in Elazığ province, which was damaged after the Kahramanmaraş earthquakes, were subjected to two-stage grinding and sieving process in the laboratory environment and the material sieved through 63 μm sieve in the last stage was used in the study.

B. *Method*

In this study, changes in the fresh state and early age mechanical properties of SCMs were investigated by substituting TWP and BWP as binder materials to cement. A water/binder (w/b) ratio of 0.46 and a total binder content of 550 kg/m^3 were taken for the SCMs, of which 6 sets were produced, one set being the reference set. EFNARC criteria provide a method of determination and limit states for important parameters such as filling ability, stability, flowability, viscosity, migration ability, segregation for self-compacting cement designs [25]. For this reason, the w/b ratio was kept constant in the mix design while the use of HRWR was kept at variable rates. TWP and BWP replacement ratio was kept between 2.5-5 wt% of the total binder and 6 different mix designs were prepared, including binary mixes. The mix design for 1m3 is given in Table 3.

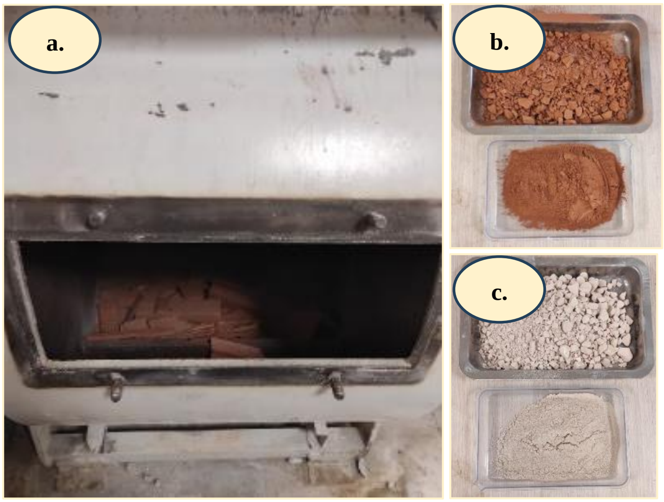

Figure 1.a. Grinding process b. Brick waste after grinding and screening c. Ceramic waste after grinding and screening

Table 3. Design of SCMs (kg/m^3)

1 m^3 (kg/m^3)					
ID	**Cement**	**HRWR**	**CS**	**TWP**	**BWP**
SCMCW0BW0	550.00	10.50	1468.50	0.00	0.00
SCMCW0BW2.5	536.25	11.00	1458.40	0.00	13.75
SCMCW2.5BW0	536.25	11.00	1461.60	13.75	0.00
SCMCW2.5BW2.5	522.50	10.30	1452.90	13.75	13.75
SCMCW0BW5	522.50	10.50	1449.50	0.00	27.50
SCMCW5BW0	522.50	11.53	1454.60	27.5	0.00

For the determination of the fresh state properties of the 6 different SCMs produced, mini-settling-diffusion test according to EFNARC and V-funnel test for viscosity determination were performed and the visuals of the study are given in Figure 2. [26, 27].

Figure 2. V-funnel and mini-slump test

The 40x40x160 mm prism and 50x50x50 mm cube specimens were kept in the laboratory for 24 hours, then demolded, coded, and matured in lime-saturated water cure until the 3rd and 7th test day.

The coding data of the specimens are given in Table 3. The 3- and 7-day prism specimens were used for void ratio and oven dry unit volume weight tests. In addition to the void ratio and oven dry unit volume weight tests, capillary water absorption and splitting tensile tests were performed on 7-day old cube specimens in accordance with the relevant standards. Figure 3 shows the visuals of the experimental study [28].

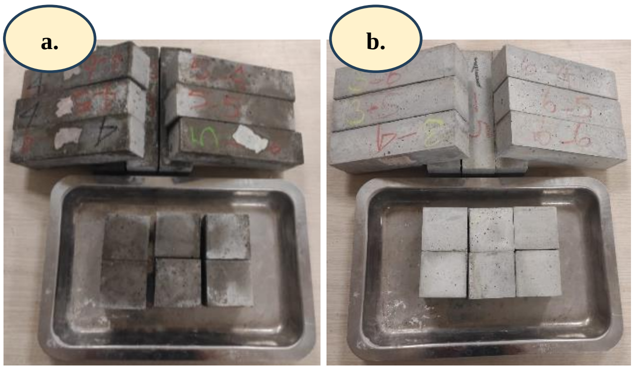

Figure 3. 7-day post-curing and oven-dried specimen sample

Prism specimens of all SCM sets were subjected to flexural tensile tests according to ASTM C348 [29] on the 3rd and 7th test days (Figure 4), followed by compressive strength tests according to ASTM C349 [30] (Figure 5).

Figure 4. General view of the specimen after flexural tensile test

Figure 5. General view of the specimen after compression test

In addition, tensile tests in splitting were performed on the 7th test day with 50x50x50 mm cube specimens (Figure 6).

Figure 6. General view of the specimen after splitting tensile test

III. RESULTS

After reaching the targeted spreading diameter values according to EFNARC and limited to 240-260 mm in all SCM sets, a V-funnel experiment was performed, and the V-funnel efficiency time was realized in the range of 7-11 s in all SCM sets. The relevant data are as presented in Table 4. In the sets with brick waste substitution, while the spreading diameter decreases with increasing substitution, the V-funnel flow time increases. However, the opposite trend is observed in SCM sets with ceramic waste substitution. These data indicate that brick waste has an impact on the important fresh state properties of workability and settleability.

Table 4. SCM Mixtures V funnel and mini slump test data

ID	Mini slump Flow diameter (mm)	V-funnel time (sn)
SCMCW0BW0	251	10.1
SCMCW0BW2.5	248	10.5
SCMCW2.5BW0	255	9.9
SCMCW2.5BW2.5	253	10.2
SCMCW0BW5	245	10.8
SCMCW5BW0	258	9.9

The porosity ratio for all SCM sets was determined comparatively for the 3rd and 7th day samples and given in Figure 7. The highest porosity ratio value was obtained in the SCMCM5BW0 set with ceramic waste additive produced with 5 wt% replacement of the binder. Porosity data are close to each other in all sets, including the reference sample set.

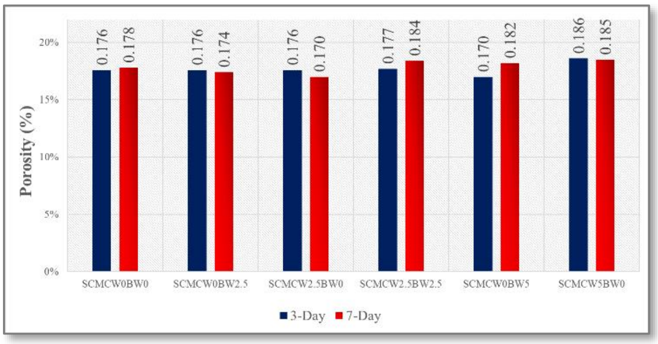

Figure 7. 3 and 7-day variation for SCM sets

The data for all sets for which oven dry unit volume weight determination was performed are as given in Figure 8. The early oven dry unit weight of the sets with 2.5-5 wt% binder substitution rate shows the highest increase of 64% in SCMCW2.5BW0 (3 days) set and the highest decrease of 8% in SCMCW5BW0 (7 days) set compared to the reference sample set. The fact that the oven-dried unit volume weight data of all substituted sets are close to the reference set is related to the fact that the substitution rate is in a low band of 2.5-5% and the substitution preference is substitution by weight.

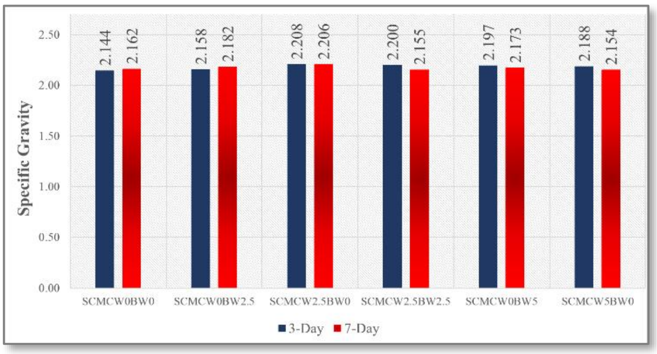

Figure 8. 3- and 7-days oven dry unit volume weight variation for SCM sets

Flexural tensile strength data for all prism specimen sets are presented in Figure 9. For all specimen sets, the flexural tensile strength increases with increasing age. All substituted sets of both 3- and 7-day old specimens were recorded with lower flexural tensile data compared to the reference set. The flexural tensile strength decreases with increasing waste replacement rate. The reference set provides a flexural tensile value of 8.38 MPa at day 3 and 12.95 at day 7. Compared to the reference specimen set, the decrease in flexural tensile value of SCMCW0BW2.5 and SCMCW0BW5 sets with 2.5% and 5% brick waste substitution was 2.25 MPa and 2.84 MPa at day 3 and 2.25 MPa and 4.23 MPa at day 7, respectively. Increasing proportion of brick waste exhibits a gradual decrease at the early age flexural tensile strength with increasing acceleration. The decrease in flexural tensile strength compared to the reference specimen set is 1.66 MPa and 1.76 MPa at day 3 and 4.56 MPa and 2.21 MPa at day 7 for SCMCW2.5BW and SCMCW5BW specimen sets with ceramic waste substitution, respectively. Although the SCMCW2.5BW2.5 specimen set designed with both ceramic and brick waste substitution provided the lowest flexural tensile strength data on the 3rd test day, it increased on the 7th test day and obtained a value of 10.15 MPa.

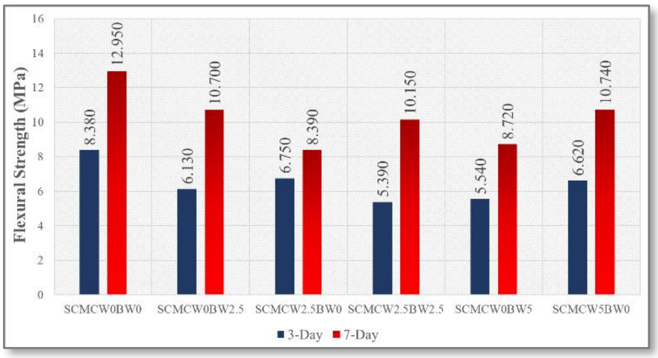

Figure 9. 3- and 7-day tensile strength variation in bending for SCM sets

The data of the compressive strength test performed after the flexural tensile test are given in Figure 10. There is an increase in the compressive strength value from test day 3 to test day 7 for the reference specimen set and all substituted sets. On test day 3, there is an increase in the compressive strength compared to the reference specimen set for all sets except SCMCW0BW2.5 and SCMCW0BW5 sets with 2.5% and 5% brick waste additives. On the 7th test day, the compressive strength value of the SCMCW0BW5 set is still low compared to the reference set, while the compressive strength value of the 2.5% substituted SCMCW0BW2.5 set has approached the reference specimen. The SCMCW2.5BW2.5 set containing both ceramic waste and brick waste has a higher compressive strength value than the reference specimen set on test days 3 and 7. The ceramic waste provides a relative increase in the compressive strength, while the brick waste has a decreasing effect.

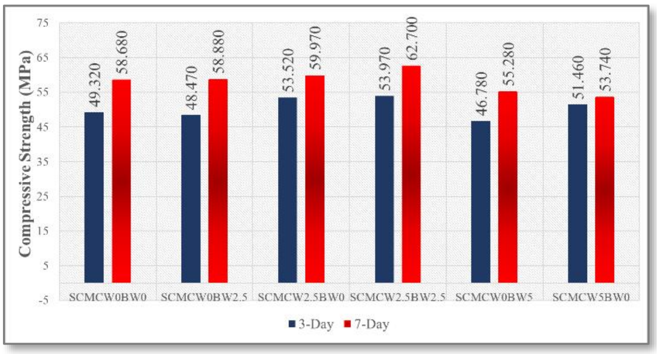

Figure 10. 3- and 7-days compressive strength variation for SCM sets

The data for the determination of the tensile strength at splitting of 50x50x50 mm 7-day old cube specimens are given in Figure 11. Compared to the reference specimen set, the splitting tensile data of all substituted sets were relatively close.

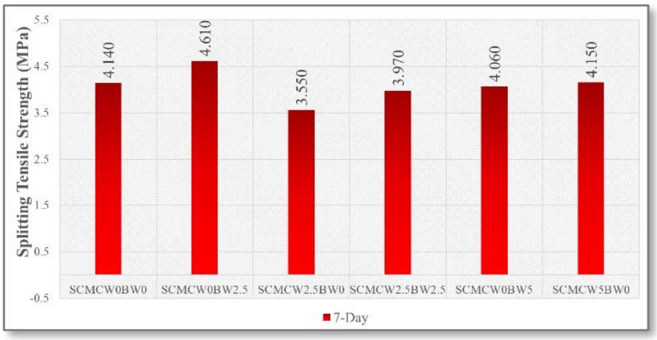

Figure 11. Splitting strength of 50x50x50 mm 7-day old cube

The capillary water absorption test provides indirect information about the porosity of mortar elements. Figure 12 shows the variation data after the capillary water absorption test performed on a single surface. After 24 hours, the highest capillary water absorption was reported for SCMCW5BW0 and SCMCW0BW5.

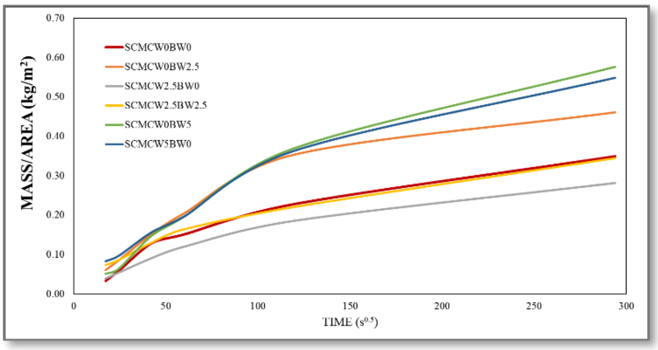

Figure 12. Sorptivity test

IV. CONCLUSIONS

The following evaluations were made as a result of the data obtained from this experimental study in which the effect of partial use of brick and ceramic waste in the range of 2.5-5% as binder substitute in mixtures produced as SCM on fresh state properties and early age mechanical properties were investigated.

- Since the fresh state properties and the workability and viscosity properties limited by the EFNARC criteria will be adversely affected after 5 wt% binder substitution, the study was carried out in the 2.5-5% band. Brick dust affects the fresh state properties and reduces the workability, viscosity and flowability.
- Brick and ceramic waste admixture have a decreasing effect on tensile strength in

bending. And this decreasing effect is 35.68% for 3-day specimens and 35.21% for 7-day specimens.

- On the compressive strength, ceramic waste has an increasing effect while brick waste has a decreasing effect. Although these effects are at a relatively low level; there is an increase in the compressive strength data compared to the reference specimen set in the specimens produced with 2.5% brick and 2.5% ceramic waste substitution as a dual design.
- Due to the amorphous structure of brick waste, an increase in capillary water absorption rate was recorded with increasing substitution rate.
- Although brick and ceramic waste has a determining effect on fresh and early age mechanical properties, it is at an acceptable level with a substitution rate of 2.5-5 wt% to the binder.

REFERENCES

[1] G. Günel, Ö. Sevim, İ. Demir & E.H. Alakara, "İkili fayans tozu, tuğla tozu ve cam tozu bazlı geopolimer kompozitlerin mekanik özelliklerinin incelenmesi" *International Conference on Applied Engineering and Natural Sciences*, 2023, 1(1), 370–373. https://doi.org/10.59287/icaens.1024

[2] N.D. Oikonomou, "Recycled Concrete Aggregates," *Cement & Concrete Composites*, 2005, 27,315-318.

[3] İ. Demir, "The Use of Demolition Waste in Concrete Production and Its Effect on Physical and Mechanical Properties" *AKÜ Afyon Kocatepe University Journal of Science and Engineering Sciences*, 2009, 2, 105 -114.

[4] M. Behera, S.K. Bhattacharyya, A.K. Minocha, R. Deoliya, and S. Maiti, "Recycled aggregate from C&D waste & its use in concrete – A breakthrough towards sustainability in construction sector: A review," *Construction and Building Materials*, 2014, 501-516.

[5] M.K. Korkut and O. Şimşek, "Investigation of Some Engineering Properties of Concrete Using Construction Wreckage Waste as Coarse Aggregate, Natural and Crushed Sand as Fine Aggregate," *International Journal of Engineering Research and Development*, 2021, 13 (2), 508-520, doi: 10.29137/umagd.879038

[6] Y. Özçelik and O. Şimşek, "Use of fine aggregate from construction debris in foam concrete production and determination of optimum water/cement ratio," *Journal of Polytechnıc,* 2023, 1-1, doi: 10.2339/politeknik.1122611

[7] M.F. Yentimur, T. Kütük Sert, and S. Kütük, "Effects of Boron and Boron Waste with Recycling Aggregate on Normal Concrete," *Journal of Innovations in Civil Engineering and Technology* (JICIVILTECH), 2022, 4(2), 47-60.

[8] H. Söylemez and O.Y. Bayraktar, "İnşaat Yıkıntı Atıklarının Asfalt Agregası Olarak Kullanılma Stratejisi," ISAS, *3rd International Symposium on Innovative Approaches in Scientific Studies*. 2019, April, Ankara, Turkey.

[9] İ. Vural, "Utilization of Construction Demolition Waste in Soil Improvement" *Academic Platform - Journal of Engineering and Science,* 2019, 7(1), 1-6, doi:10.21541/apjes.437288

[10] İ.B. Topçu and S. Şengel, "Properties of Concretes Produced with Waste Concrete Aggregate," *Cem Concr Res*., 2004, 34, 8, 1307-1312.

[11] L. Xu, W. Su and T. Su, "Influence of recycled clay brick aggregate on the mechanical properties of concrete," *Reviews on Advanced Materials Science*, 2022, 61: 372–380, doi: 10.1515/rams-2022-0034

[12] M. Tuyan, "Effect of Use of Waste Clay Brick Powder as Mineral Admixture on Fresh, Mechanical and Durability Properties of Self-Consolidating Concrete," *Süleyman Demirel University Journal of Natural and Applied Sciences*, 2019, 23 (2), 540-548, doi: 10.19113/sdufenbed.547882

[13] M. Heikal, K.M. Zohdy, and M. Abdelkreem, "Mechanical, microstructure and rheological characteristics of high performance selfcompacting cement pastes and concrete containing ground clay bricks," *Construction and Building Materials*, 2013, 38, 101-109

[14] H.J. Chen, T. Yen and K.H. Chen, "Use of Building Rubbles as Recycled Aggregates," *Cement and Concrete Research*, *2003*, 33, 125-132

[15] G. Lu, Z. Fan, Z. Sun, P. Liu, Z.Leng, D. Wang, M. Oeser "Improving the polishing resistance of cement mortar by using recycled ceramic," *Resources, Conservation and Recycling*, 2020, 158(104796), doi:10.1016/j.resconrec.2020.104796

[16] J. de Brito, A.S. Pereira, J.R. Correia, "Mechanical behaviour of non-structural concrete made with recycled ceramic aggregates," *Cement Concr. Compos.*, 2005, 27 (4), 429-433

[17] X. Chen, D. Zuyong, S. Cheng X. Xu, C. Zhao, X.Wang, O. Wu, X.Bai, "Sustainable reuse of ceramic waste powder as a supplementary cementitious material in recycled aggregate concrete: Mechanical properties, durability and microstructure assessment," *Journal of Building Engineering*, 2022, 52(104418), doi:10.1016/j.jobe.2022.104418

[18] G. Kalınçimen, A.U. Öztürk, G. Kaplan, and S.A. Yıldızel, "Seramik Atıklarının Çimento İkame Malzemesi Olarak Kullanılması ve Asit Dayanıklılığının İncelenmesi," *Kastamonu University Journal of Engineering and Sciences*, 2015, 1(1), 9-16.

[19] P. R. Matos, R. D. Sakata, L. Onghero, V.G. Uliano , J.de Brito , C. E.M. Campos, P.J.P. Gleize, "Utilization of ceramic tile demolition waste as supplementary cementitious material: An early-age investigation",

Journal of Building Engineering, 2021, 38, doi:10.1016/j.jobe.2021.102187

[20] S. Subaşı, H. Öztürk, M. Emiroğlu, “Utilizing of waste ceramic powders as filler material in self-consolidating concrete,” *Construction and Building Materials,* 2017, 149, 567-574,

[21] TS EN 197-1. (2011). Cement–Part 1: Composition, specifications and conformity criteria for common cements. Türk Standartları Enstitüsü .

[22] TS EN 1008. Mixing water for concrete - Specifications for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete. Türk Standartları Enstitüsü, Ankara. 2003.

[23] TS EN 933-1. Tests for geometrical properties of agregates Part 1: Determination of particle size distribution sieving method. Türk Standartları Enstitüsü, Ankara. 2012.

[24] TS EN 934-2+A1. Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling. Türk Standartları Enstitüsü, Ankara. 2013

[25] S. Etli, M. Akgül, “Water Absorption in Self-Compacting Mortars with Variable Water/Cement Ratio,” 1st International Conference on Frontiers in Academic Research, February 18-21, 2023 : Konya, Turkey.

[26] EFNARC. Specifications and Guidelines for Self-Compacting Concrete. EFNARC, Association House, 99 West Street, Farnham, UK, www.efnarc.org, ISBN 0 953973344, 32. 2002.

[27] EFNARC & The European Project Group, The European Guidelines for Self-Compacting Concrete Specification, Production and Use. The European Guidelines for Self Compacting Concrete. May, 63.2005.

[28] TS EN 12390-1. Beton- Sertleşmiş beton deneyleri- Bölüm 1: Deney numunesi ve kalıplarının şekil, boyut ve diğer özellikleri. *Türk Standartları Enstitüsü, Ankara.* 2013

[29] ASTM C348-19. (2018). Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars. Annual Book of ASTM Standards, 03(Reapproved), 98–100.

[30] ASTM C349-08. (2008). Standard test method for compressive strength of hydraulic-cement mortars (using portions of prisms broken in flexure). ASTM International, 1–4.