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Research Article / Araştırma Makalesi

PREPARATION OF GAS CONCRETE MATERIALS FROM VARIOUS INDUSTRIAL WASTE

Nevin KARAMAHMUT MERMER, Müge SARI YILMAZ, Sabriye PİŞKİN*

Yildiz Technical University, Faculty of Chemical and Metallurgical Enginnering, Chemical Engineering Department, Esenler-ISTANBUL

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ABSTRACT

Construction materials are being used primarily for the humans' basic shelter needs since the beginning of history. Also, construction sector continues to evolve with the constantly advancing technology and it is one of the most important and largest sectors together with textile and food in the world. Gas concrete, which is a type of lightweight concrete's, usage has increased due to its minimal energy losses and light weight. With the additives that uses in gas concrete and creating pores with them, the structure can gain lightness and insulating properties.
In this study, the gas concrete samples have been prepared with different methods using various industrial wastes as aggregate. Two different mixing types including by hand and with mechanical stirrer were used to see the impact of mixing type to the strength. Characterization and compressive strength values of the prepared samples were determined by comparing the best aggregate types. Gas concrete has been prepared both under the pressure and temperature in autoclaved conditions and the room conditions separately to see the effect of using the autoclave. According to analysis result, the gas concrete sample prepared from Afsin Elbistan fly ash and sand mixture had the best compressive strength of 1.09 N/mm^2 and it was classified as G1 class regarding to TS 453.
Keywords: Gas concrete, gold mine tailing slurry, fly ash, lightweight concrete.

ÇEŞİTLİ ENDÜSTRİYEL ATIKLARDAN GAZ BETON ÜRETİMİ

ÖZ

Yapı malzemeleri insanlık tarihinin başlangıcından beri, insanlık için temel ihtiyaç olan barınma başta olmak üzere çeşitli alanlarda kullanılmakta ve ilerleyen teknoloji ile sürekli gelişmeye devam etmektedir. Yapı sektörü, tekstil ve gıda sektörleri ile birlikte tüm dünyada en önemli ve en büyük sektörlerden biridir. Bir hafif beton çeşidi olan gaz betonun, enerji kayıplarını en aza indirme ve hafif olması gibi özellikleri nedeni ile yüksek yapıların inşaasında ve deprem bölgelerindeki kullanımı artmıştır. Gaz betonlarda kullanılan katkı maddeleri ile yapıda gözenek oluşturularak malzemeye hafiflik ve yalıtım özellikleri kazandırılmaktadır.
Çalışma kapsamında agrega olarak çeşitli sanayi atıkları kullanılarak farklı karışımlarla ve yöntemlerle gaz beton numuneleri hazırlanmıştır. Elle ve manyetik karıştırıcı ile karıştırma olmak üzere iki farklı karıştırma yöntemi uygulanmış ve karıştırma işleminin mukavemet üzerindeki etkisi incelenmiştir. Hazırlanan örneklerin karakterizasyon analizleri ile basınç mukavemet testleri gerçekleştirilmiştir. Buna ek olarak, kum ve atıklardan hazırlanan karışımlar, kürlenme işlemi için otoklavda bekletilerek basınç mukavemet değerleri tespit edilmiştir.
Analiz sonuçlarına göre, Afsin Elbistan uçucu külü ve kum karışımından hazırlanan gaz beton numunesi 1.09 N/mm^2'lik en iyi mukavemet değerine sahip olduğu ve TS 453'e göre sınıfı G1 olarak bulunmuştur.
Anahtar Sözcükler: Gaz beton, altın madeni arıtma çamuru, uçucu kül, hafif beton.

* Corresponding Author/Sorumlu Yazar: e-mail/e-ileti: piskin@yildiz.edu.tr, tel: (212) 383 47 29

1. INTRODUCTION

Concrete is a readily available raw material which is most widely used for the construction industry. Basic physical and chemical properties of concrete are variable due to the application area [1]. The main components of concrete are cement, aggregates and water. The major properties of concrete depend's on aggregates, which is the component with the highest amount in the composition. Cement is the binding function of the concrete. Therefore the alignment of the cement with the aggregate determines the life of the concrete [2]. Due to the changing demands, different types of concrete had been developed and one of them is the lightweight concrete. Compared to the standard concrete, lightweight concrete has a lower intensity, high insulating properties and low strength values [3].

Aerated concrete can be classified according to the agents that have been used to introduce the porosity in the structure of it. Aerated concrete can be produced by introducing air entraining agent, gas forming chemicals and foaming agents [4]. Gas concrete is lighter than the conventional concrete with a dry density of 300 kg/m^3 up to 1840 kg/m^3; 87 to 23% lighter [5].
In the literature there are two methods to prepare the gas concrete. The first method is to inject the gas into the mixing during its plastic condition. In the second method, air is introduced by either with mixing-in stable foam or by whipping-in air, using an air-entraining agent [6].

To the author's knowledge, there have been no studies the usage of gold mine tailings slurry as an aggregate on the preparation of gas concrete. In this study, gold mine tailings slurry, thermal power plant fly ashes from different regions that provided from Afsin-Elbistan, Catalagzi, Orhaneli, Seyitomer, and Tuncbilek were used as aggregate in the production of gas concrete. To compare the properties of the prepared samples, sand was used as a reference aggregate. The characterization of raw materials were determined by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and X-ray fluorescence (XRF) analysis.

2. EXPERIMENTAL SECTION

2.1. Materials

In the experiments, as the main component of the concrete, Akcansa Grey Pordland Cement (CEM I 42.5R) was used. Sand used as a reference aggregate obtained from Esen Mining, Istanbul. Gold mine tailings slurry used in the present study was obtained from the Bergama Ovacik Gold Mine Treatment Plant, Turkey. Fly ashes were received from different regions that provided from Afsin-Elbistan, Catalagzi, Orhaneli, Seyitomer, and Tuncbilek thermal power plant. Quicklime and gypsum were obtained from Akyuz Lime, Ankara and Kilicoglu Mining, Istanbul, respectively. The Al powder used as a gasifying agent was supplied from Holland.

2.2. Instruments and Methods

The crystallinity of the raw materials and prepared samples were determined by using a Philips Panalytical X'Pert-Pro X-ray diffractometer with CuKα tube and parameters of 45 kV and 40 mA. The chemical composition of the raw materials and samples were carried out Philips Panalytical Minipal XRF spectrometer. The characteristic bands of the raw materials and samples were determined in a Perkin Elmer Spectrum One FT-IR Spectrometer in a measurement range of 4000-450 cm^{-1} with 4 repetitions scanning. Compressive strength of the prepared samples was determined by Mohr&Federhaff AG brand tensile/compression test machine. For the homogenisation of the prepared mixture, Heidolph mechanical stirrer was used. To improve strength values and physical properties of the sample, curing was carried out in an autoclave at high pressure and temperature.

2.3. Preparation of Mixtures

In the present work, all types of fly ashes, gold mine tailings slurry and sand has been called as aggregate. Unary and binary aggregates were prepared to see the effect of the aggregate and aggregate combination. Two different mixing types as stirring by hand and mechanical stirrer, were applied to the mortar to see the influence of the stirring type on the mechanical strength. In the hand mixing process, mortar was mixed by spatula for 15 minutes until the samples get homogeneus. For the mechanical stirring, samples were mixed by a mechanical stirrer for 1 hour. For unary aggregate, the composition of mixture was %21-24 agregate (fly ashes or tailings slurry) 13-17% cement, 5-10% quicklime, 1-5% gypsum, 0.5-5% Al powder, and 30-40% water. For binary aggreagate, 10-16% sand (S) was added into this mixture. Samples prepared from Afsin-Elbistan, Catalagzi, Orhaneli, Seyitomer, and Tuncbilek fly ashes and gold mine tailings slurry for unary aggregate denoted as GC_A, GC_C, GC_O, GC_S, GC_T, and GC_G, respectively and for binary aggregate denoted as GC_{A+S}, GC_{C+S}, GC_{O+S}, GC_{S+S}, GC_{T+S}, and GC_{G+S}, respectively. In addition, non- autoclaved samples were waited at 25°C for curing, the autoclaved samples were treated in an autoclave at 100-210°C temperature and 8-12 bar preassure.

3. RESULT AND DISCUSSIONS

3.1. Characterization of the Raw Materials

The XRD pattern of the aggregates was given in Figure 1. The main phases of fly ashes were quartz, mullite, hematite, ferrosilite, calcite, anhydrite, portlandite, and gehlenite [7]. The main phases of Bergama Gold Mine tailings slurry were silicon dioxide and aluminum oxide [8].

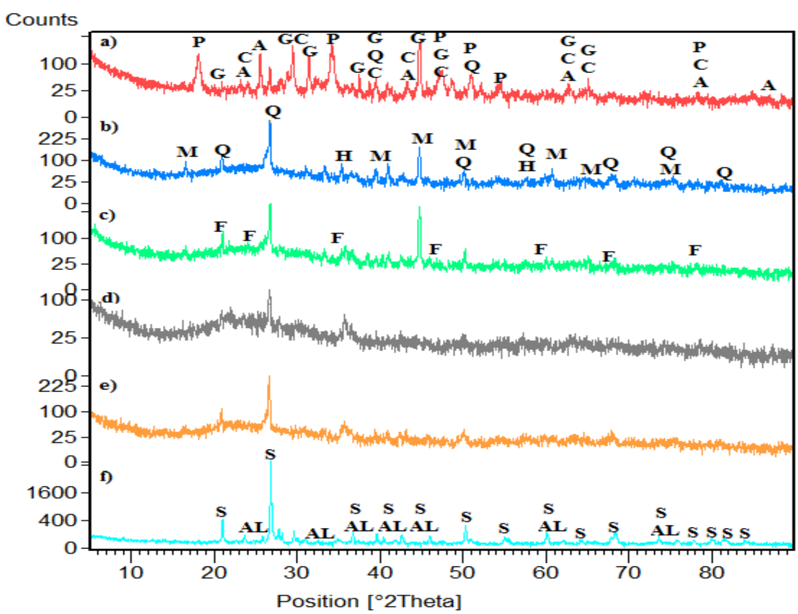


Figure 1. XRD pattern of aggregates a)Afsinelbistan fly ash, b)Catalagzi fly ash, c)Orhaneli fly ash, d) Seyitomer fly ash, e)Tuncbilek fly ash, f) Bergama gold mine tailing slurry Q: quartz, H: hematite, M: mullite, F: ferrosilite, P: portlandite, C: calcite, A: anhydrite, G: gehlenite, S: SiO_2, and AL: Al_2O_3)

3.2. Characterization of the non-autoclaved gas concrete samples

Chemical compositions of the samples prepared by mechanical stirring from binary aggregate were listed in Table 1. The main components of the samples were SiO_2 and CaO.

Table 1. XRF analysis of the prepared gas concrete samples

Chemical Composition (%)	GC_{G+S}	GC_{A+S}	GC_{O+S}	GC_{C+S}	GC_{S+S}	GC_{T+S}
MgO	3	4	2	2	10	4
Al_2O_3	7.4	4.2	11	16	8.9	12
SiO_2	35.5	14	29.1	35	27.6	36.4
SO_3	4	6.33	3.3	2.4	2.4	2.6
K_2O	2.79	0.94	2.39	4.46	2.53	1.92
CaO	42.3	67	41.5	31	32.1	29.8
Fe_2O_3	5.32	3.62	10.3	8.93	16.8	14.1

XRD pattern of the prepared samples was given in Figure 2. From the figure, the main phases were waste, cement, gypsum, sand, and quicklime. There was no peak related to the aluminum powder due to ratio to total material less than 5%.

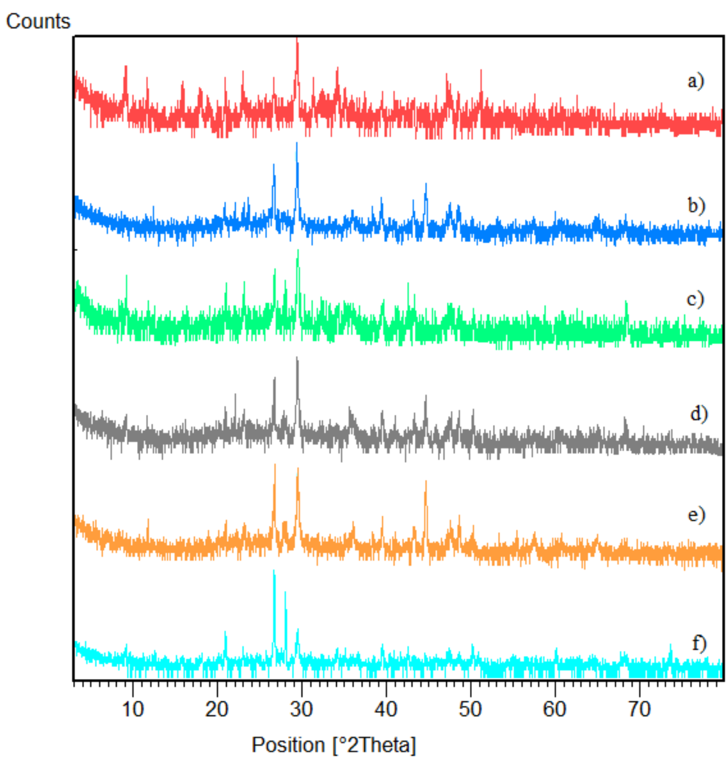
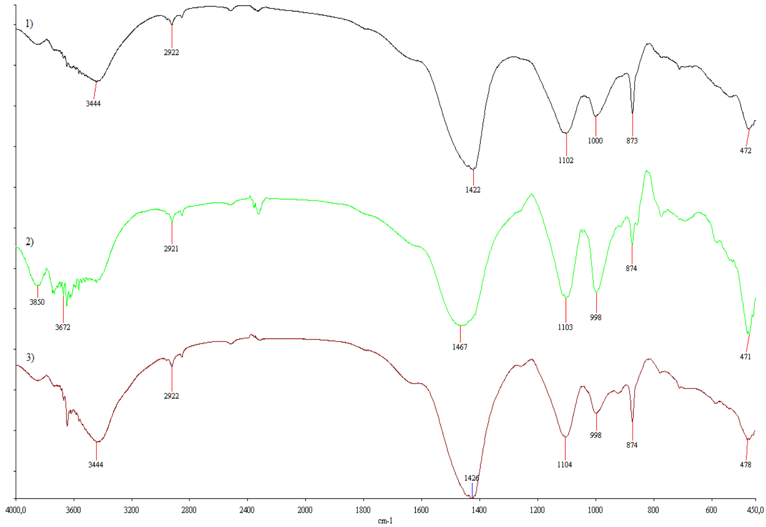
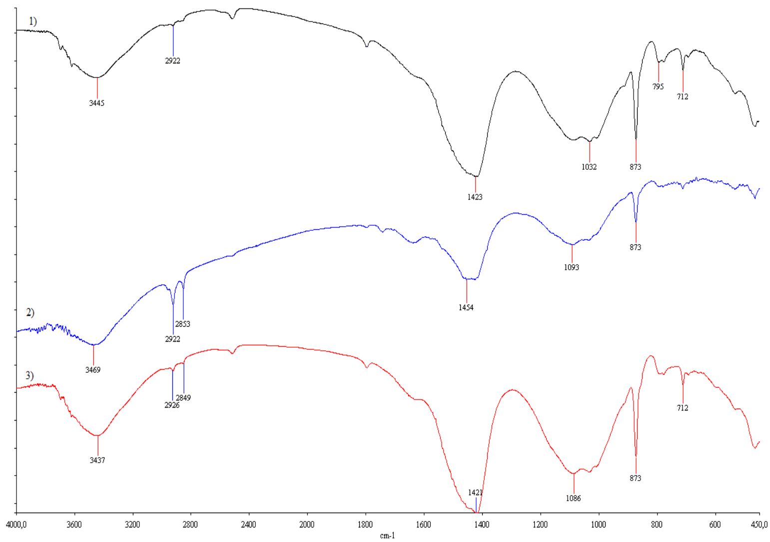


Figure 2. XRD pattern of prepared samples a) GC_{A+S}, b)GC_{C+S}, c) GC_{O+S}, d) GC_{S+S}, e) GC_{T+S}, and f)GC_{G+S}

FTIR spectra of the samples prepared by mechanical stirring from binary aggregate were given in Figure 3 a) and b). Adsorption band in the range of 3437-2850 cm^{-1} shows the weakly bound of OH and H-O-H group's stretching vibration and deformation. The peaks at 1032-1102 cm^{-1} and 873 cm^{-1} attributed to the Si-O-Si symmetric and asymmetric stretching. The peaks at the 1000-998 cm^{-1} corresponded the Si-O-Si and Al-O-Si asymmetric stretching vibrations [9, 10]. The adsorption band in the range of 1467-1421 cm^{-1} attributed to CaO vibrations [11]. The other peaks between 471 and 478 cm^{-1} assigned to Si-O and Al-O symmetric vibrations [12].



a)



b)

Figure 3. FTIR spectra of the prepared gas concrete samples a) 1) GC_{O+S}, 2) GC_{G+S}, 3) GC_{A+S} and b) 1) GC_{T+S}, 2) GC_{C+S}, 3) GC_{S+S}

The mechanical strength values of all the prepared samples were given in the Table 2. According to the results, compression strength values of the samples prepared by hand mixing were lower than the strength values of the samples prepared by mechanical stirring. Mechanical stirring provided uniform distrubition, results in a positive effect on the mechanical strength. In addition, the samples prepared from the binary aggregates are observed to have increased strength values with the addition of sand. Also, it can be seen that the best compressive strength sample is prepared from Afsin Elbistan fly ash and sand mixture.

Table 2. Mechanical strength of the prepared samples

Hand Mixing				Mechanical stirring	
Unary Aggregate		Binary Aggregate		Non-autoclaved	
Sample name	Strength (N/mm^2)	Sample name	Strength (N/mm^2)	Sample name	Strength (N/mm^2)
GC_G	0,03	GC_{G+S}	0,13	GC_{G+S}	0,19
GC_A	0,06	GC_{A+S}	0,19	GC_{A+S}	0,49
GC_O	0,06	GC_{O+S}	0,13	GC_{O+S}	0,14
GC_C	0,12	GC_{C+S}	0,15	GC_{C+S}	0,21
GC_S	0,15	GC_{S+S}	0,18	GC_{S+S}	0,27
GC_T	0,10	GC_{T+S}	0,16	GC_{T+S}	0,28
S	0,10	-	-	-	-

3.3. Characterization of the Autoclaved Gas Concrete Samples

The images of the autoclaved gas concrete samples were demonstrate in Figure 4. Physical properties of gas concrete such as strength, shrinkage, and insulation are related to the porosity and pore size distribution [13]. It was seen that autoclaved GC_{A+S} and GC_{T+S} samples have the uniform pore distributions. The uniform pore size distribution has affected the strength values of samples.

Mechanical strength values of the prepared and autoclaved samples were listed in Table 3. As observed, the usage of the autoclave in the curing stage significantly increased the strength of all the samples. The samples with the name AGC_{A+S}, AGC_{S+S}, and AGC_{T+S} have classified the G1 class according to TS 453 standard.

Table 3. Mechanical strength and classification of the autoclaved samples [14]

Sample name	Strength (N/mm^2)	Classification
AGC_{G+S}	0.70	-
AGC_{A+S}	1.09	G1
AGC_{O+S}	0.66	-
AGC_{C+S}	0.81	-
AGC_{S+S}	1.01	G1
AGC_{T+S}	1.05	G1

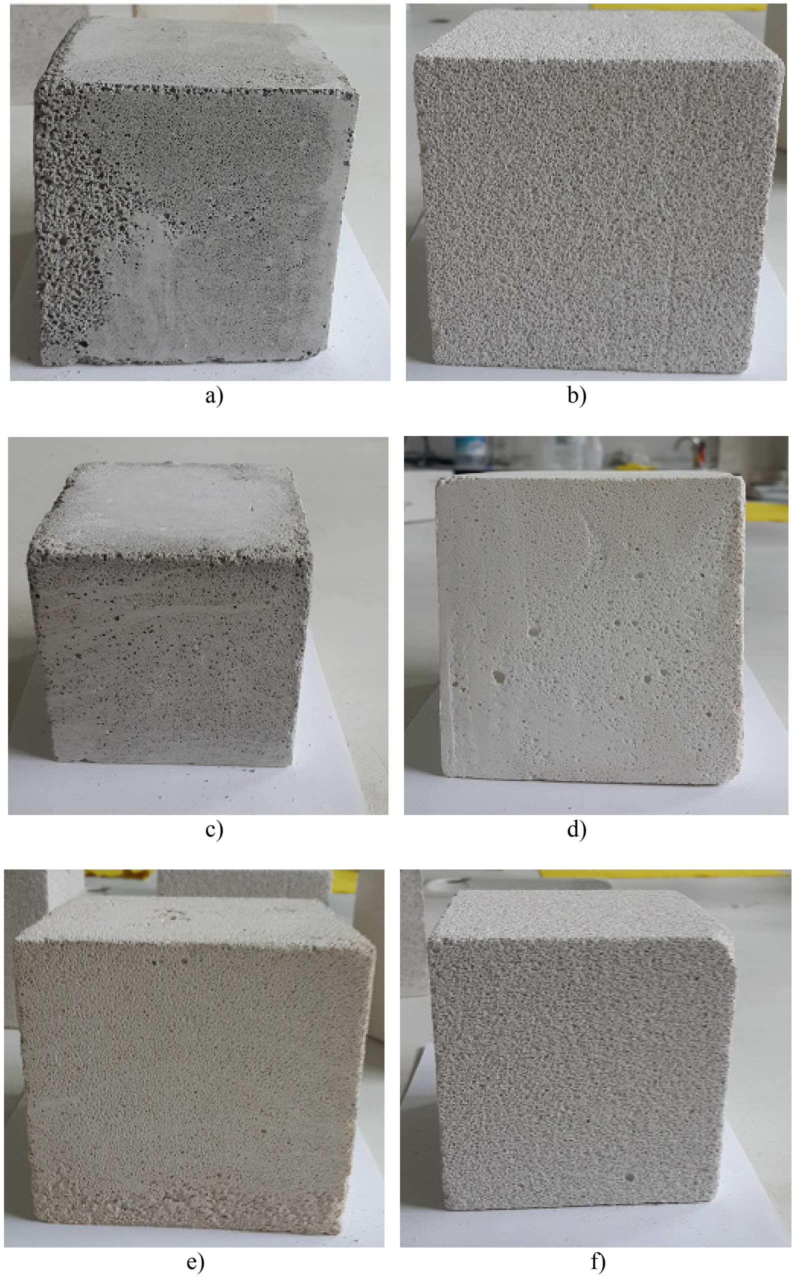


Figure 4. Images of the autoclaved samples a) AGC_{G+S}, b) AGC_{A+S}, c) AGC_{O+S}, d) AGC_{C+S}, e) AGC_{S+S} , f) AGC_{T+S}

4. CONCLUSION

In this study, gas concrete samples prepared from different methods by using of gold mine tailings slurry, thermal power plant fly ashes from different regions of Turkey and sand as an aggregate. The gold mine tailings slurry was used as an aggregate in the preparation of gas concrete for the first time. The unary aggregate and hand mixing process were applied to preparation of the gas concrete samples. Due to the low strength values of the prepared unary aggregate system, sand has been added to the aggregate to increase of the strength. It was seen that mechanical stirring increased of the strength according to manually stirring. In addition, when the curing stage was carried out in an autoclave, the mechanical strength of the samples increased. Results show that the best mechanical strength in the sample prepared in the autoclave was observed for GC_{A+S} sample. With the usage of Afsin Elbistan fly ash and the sand mixture at the gas concrete production, there will be a new usage area for this waste and this situation will contribute both the environment and the production economy of the gas concrete.

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Abbreviations

TS :	Turkish Standard
XRD :	X-ray diffraction
FT-IR :	Fourier transform infrared spectroscopy
XRF:	X-ray fluorescence
GC_A:	Gas concrete prepared from Afsinelbistan fly ash
GC_C:	Gas concrete prepared from Catalagzi fly ash
GC_O:	Gas concrete prepared from Orhaneli fly ash
GC_S :	Gas concrete prepared from Seyitomer fly ash
GC_T :	Gas concrete prepared from Tuncbilek fly ash
GC_G :	Gas concrete prepared from gold mine tailing slurry
GC_{A+S} :	Gas concrete prepared from Afsinelbistan fly ash and sand
GC_{C+S} :	Gas concrete prepared from Catalagzi fly ash and sand
GC_{S+S} :	Gas concrete prepared from Seyitomer fly ash and sand
GC_{O+S}:	Gas concrete prepared from Orhaneli fly ash and sand
GC_{T+S} :	Gas concrete prepared from Tuncbilek fly ash and sand
GC_{G+S} :	Gas concrete prepared from gold mine tailing slurry and sand
AGC_{G+S} :	Autoclaved gas concrete prepared from gold mine tailing slurry and sand
AGC_{A+S} :	Autoclaved gas concrete prepared from Afsinelbistan fly ash and sand
AGC_{O+S} :	Autoclaved gas concrete prepared from Orhaneli fly ash and sand
AGC_{C+S} :	Autoclaved gas concrete prepared from Catalagzi fly ash and sand
AGC_{S+S} :	Autoclaved gas concrete prepared from Seyitomer fly ash and sand
AGC_{T+S} :	Autoclaved gas concrete prepared from Tuncbilek fly ash and sand

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