Majdi, HS, Shubbar, AAF, Nasr, MS, Al-Khafaji, ZS, Jafer, H, Abdulredha, M, Al Masoodi, Z, Sadique, MM and Hashim, KS

Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations

Article Title

Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations

Authors

Hasan Sh. Majdi [1], Ali Abdulhussein Shubbar [2, 3,*], Mohammed Salah Nasr [4], Zainab S. Al-Khafaji [1,5], Hassnen Jafer [3], Muhammad Abdulredha [6], Zainab Al Masoodi [7], Monower Sadique [2], Khalid Hashim [2]

Affiliations

1. Department of Chemical Engineering and Petroleum Industries, Al - Mustaqbal University College, Hillah, Iraq
2. Department of Civil Engineering, Liverpool John Moores University, Henry Cotton Building, Webster Street, Liverpool L3 2ET, UK
3. Department of Civil Engineering, College of Engineering, University of Babylon, Babylon, Iraq
4. Babylon Technical Institute, Al-Furat Al-Awsat Technical University, 51015 Babylon, Iraq
5. Al-Furrat Al-Awsat Distribution Foundation \ Ministry of Oil \ Babylon, Iraq.
6. Department of Civil Engineering, College of Engineering, University of Kerbala, Kerbala, Iraq
7. Ministry of Construction and Housing, National Center for Construction Laboratories (NCCL), Babylon, Iraq.

Corresponding author(s)

A.A.SHUBBAR@2014.LJMU.AC.UK, alishubbar993@gmail.com (A.A.Shubbar)

Abstract

The development in the construction sector and population growth requires an increase in the consumption of construction materials, mainly concrete. Cement is the binder in concrete, so increasing cement production will increase the energy consumed, as well as in the emission of carbon dioxide. This harmful effect of the environment led to the search for alternative materials for cement, as the waste or by-products of other industries is a promising solution in this case. Among these common materials are ground granulated blast furnace slag (GGBS) and cement kiln dust (CKD). This dataset describes the compressive strength and ultrasonic pulse velocity of mortar consisted of high content of GGBS and CKD combinations as a partial substitute for cement (up to 80%) at the ages of 1, 2, 3, 7, 14, 21, 28, 56, 90 and 550 days. This dataset can help the researchers to understand the behaviour of GGBS and CKD in high replacement levels for cement during early (1 day) and later ages (550 days). According to this understanding, the authors believe that the data available here can be used to produce more environmentally friendly mortar or concrete mixtures by significantly reducing the amount of cement used by replacing it with waste or by-products of other industries.

Keywords

Cement replacement, high replacement level, compressive strength, ultrasonic pulse velocity

Specifications Table

Subject	Civil engineering
Specific subject area	Building Materials, Concrete Technology, Mechanical and Durability Properties
Type of data	Tables, Figures and Images.
How data were acquired	Laboratory Experiments
Data format	Raw and Analysed
Parameters for data collection	Three different percentages of GGBS and CKD combinations are replaced the cement in a high levels (as well as the reference mixture without replacement) to produce sustainable mortar.
Description of data collection	Data was obtained from laboratory experiments at the ages of 1, 2, 3, 7, 14, 21, 28, 56, 90 and 550 days of compressive strength and ultrasonic pulse velocity properties of the hardened mortar
Data source location	Liverpool, United Kingdom

Data accessibility	The data are available within this article
Related research article	Shubbar, Ali Abdulhussein, Hassnen Jafer, Muhammad Abdulredha, Zainab S. Al-Khafaji, Mohammed Salah Nasr, Zainab Al Masoodi, and Monower Sadique. "Properties of cement mortar incorporated high volume fraction of GGBFS and CKD from 1 day to 550 days." Journal of Building Engineering (2020): 101327. https://doi.org/10.1016/j.jobe.2020.101327

Value of the Data

- This data composed of alternative cement materials in the concrete industry for building construction.
- The information provided by this data are useful to find a significant solution to environmental problems through the re-use of industrial waste in new other applications as well as reducing the CO_2 emissions that result from the cement industry.
- The data in this article is beneficial in producing sustainable mortar in which cement content is significantly reduced.
- This data helps others to understand the behaviour of hardened mortar containing high levels of GGBS and CKD during early and later ages.

Data Description

The dataset provided here represented the information for examining the compressive strength and ultrasonic pulse velocity (UPV) properties of the hardened mortar containing different combinations of Ground Granulated Blast Furnace Slag (GGBFS) and cement Kiln Dust (CKD) (in a high volume fraction) as alternatives of cement. Four mixtures were implemented, Control (reference mix without replacement) and three other mixtures included replacing the cement (by weight) with GGBFS and CKD combinations which designated as follows: T40 (26.7% GGBFS +13.3% CKD), T60 (40% GGBFS + 20% CKD), T80 (53.3% GGBFS + 26.7% CKD). The details of these mixtures can be found in [1]. The compressive strength and UPV tests were examined at 1, 2, 3, 7, 14, 21, 28, 56, 90 and 550 days of curing. The test results for Control, T40, T60 and T80 mixtures respectively are shown in Tables 1, 2, 3 and 4 (as well as in Figures 1, 2, 3 and 4) for compressive strength and in Tables 5, 6, 7 and 8 (as well as in Figures 5, 6, 7 and 8) for UPV. More detailed information about the compressive strength and UPV data can be found in the supplementary Excel datasets and in Ref. [1].

Experimental Design, Materials, and Methods

The main aim of using GGBFS and CKD as cement replacement materials is to reduce the environmental burden of cement manufacturing. For example, the cement industry consumes high energy as well as emits a high amount of CO_2 into the atmosphere [2-7]. The cement industry contributes about 7% of CO_2 production worldwide [8-13]. The laboratory work was conducted through the utilisation of different combinations of these materials in the production of mortar i.e no course aggregate was used in all mixtures. For all mixtures, the water to binder (W/B) ratio and sand to binder (S/B) ratio was fixed as 0.4 and 2.5, respectively. The GGBFS/CKD ratio in all the investigated mixtures was 2. The mortars were cast in 100 X 100 X 100 mm cubes for UPV measurements according to BS 1881-203 [14] while the prism moulds with the dimensions of 40 x 40 x 160 mm were used for compressive strength measurements according to BS EN 196-1 [15]. More data (images) about the method of mixing, preparation of samples, curing, state of samples before testing and experimental setups of the UPV and compressive strength tests are illustrated in Figures 9 to 11.

Table 1. Results of the compressive strength (MPa) for the Control mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	8.75	17.1	23.34	30.67	35.84	35.81	40.14	38.82	40.7	44.24
Sample 2	8.41	16.9	23.25	34.52	35.72	37.41	37.47	39.63	40.8	44.31
Sample 3	7.97	17.2	22.03	34.03	36.11	36.92	34.55	39	40.9	44.16
Sample 4	8.47	17.3	24.97	33.2	35.91	37.42	37.42	39.22	40.4	44.26
Average	**8.40**	**17.13**	**23.40**	**33.11**	**35.90**	**36.89**	**37.40**	**39.17**	**40.70**	**44.24**

Table 2. Results of the compressive strength (MPa) for T40 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	10.51	10.22	10.91	23.21	29.33	32.27	39.11	39.23	39.12	45.21
Sample 2	9.37	11.40	11.65	22.89	28.64	33.10	37.07	38.24	40.14	44.12
Sample 3	9.61	9.96	10.39	22.73	27.60	31.64	39.06	38.17	41.30	43.60
Sample 4	9.47	9.36	10.47	23.04	26.98	31.44	37.30	38.30	40.13	43.78
Average	**9.74**	**10.24**	**10.86**	**22.97**	**28.14**	**32.11**	**38.14**	**38.49**	**40.17**	**44.18**

Table 3. Results of the compressive strength (MPa) for T60 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	4.67	6.84	9.58	23.18	23.88	29.88	36.94	36.8	40.62	43.41
Sample 2	3.95	7.81	8.93	22.64	24.87	28.96	35.97	37.62	39.75	43.52
Sample 3	4.74	7.4	9.74	22.34	24.76	29.55	37.77	37.47	39.62	41.34
Sample 4	4.94	7.29	10.11	22.22	25.12	30.02	36.75	38.72	40.33	41.42
Average	**4.58**	**7.34**	**9.59**	**22.60**	**24.66**	**29.60**	**36.86**	**37.65**	**40.08**	**42.42**

Table 4. Results of the compressive strength (MPa) for T80 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	3.21	6.80	8.94	22.11	23.40	25.11	26.14	33.17	33.29	34.42
Sample 2	3.22	6.41	9.40	21.80	22.14	24.66	27.11	33.28	33.17	33.12
Sample 3	3.08	7.40	8.94	21.62	21.88	26.10	25.18	32.98	33.30	33.40
Sample 4	3.08	6.70	9.40	21.44	22.11	24.12	26.12	33.19	33.33	33.16
Average	**3.15**	**6.83**	**9.17**	**21.74**	**22.38**	**25.00**	**26.14**	**33.16**	**33.27**	**33.53**

Table 5. Results of the UPV (m/s) for the Control mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	3175	3891	4032	4201	4202	4292	4310	4356	4453	4478
Sample 2	3181	3922	4082	4190	4238	4298	4304	4374	4478	4490
Sample 3	3195	3912	4055	4182	4237	4310	4292	4358	4452	4480
Sample 4	3187	3910	4051	4178	4274	4292	4310	4376	4456	4502
Average	**3185**	**3909**	**4055**	**4188**	**4238**	**4298**	**4304**	**4366**	**4460**	**4488**

Table 6. Results of the UPV (m/s) for T40 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	2718	3551	3757	3974	4104	4122	4167	4216	4229	4299
Sample 2	2735	3543	3775	3997	4110	4128	4174	4226	4232	4317
Sample 3	2738	3547	3771	4022	4115	4172	4172	4214	4224	4311
Sample 4	2750	3548	3781	3995	4110	4140	4190	4211	4229	4317
Average	**2735**	**3547**	**3771**	**3997**	**4110**	**4141**	**4176**	**4216**	**4228**	**4311**

Table 7. Results of the UPV (m/s) for T60 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	2641	3509	3721	3984	4087	4082	4149	4191	4197	4282
Sample 2	2688	3497	3721	4000	4082	4104	4162	4196	4199	4292
Sample 3	2666	3502	3733	3992	4098	4149	4149	4188	4201	4292
Sample 4	2668	3503	3714	3992	4082	4082	4184	4182	4202	4254
Average	**2666**	**3503**	**3722**	**3992**	**4087**	**4104**	**4161**	**4189**	**4200**	**4280**

Table 8. Results of the UPV (m/s) for T80 mixture.

	1 day	2 days	3 days	7 days	14 days	21 days	28 days	56 days	90 days	550 days
Sample 1	2579	3234	3540	3934	3945	4024	4051	4072	4084	4118
Sample 2	2593	3221	3564	3899	3969	4034	4053	4073	4078	4130
Sample 3	2581	3221	3560	3924	3991	4039	4028	4074	4084	4152
Sample 4	2566	3220	3561	3912	3974	4042	4082	4074	4079	4134
Average	**2580**	**3224**	**3556**	**3917**	**3970**	**4035**	**4054**	**4073**	**4081**	**4133**

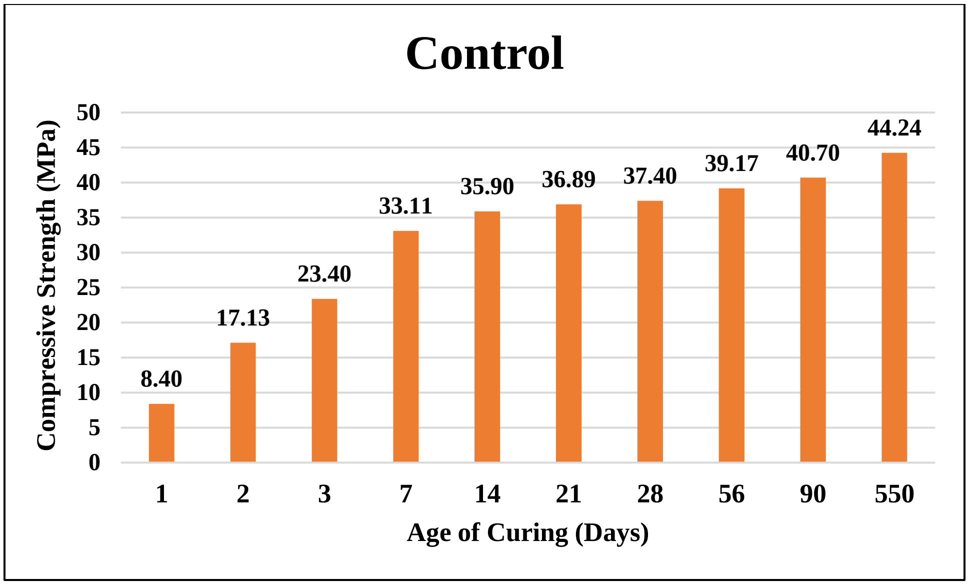

Figure 1. Average compressive strength of the Control mixture.

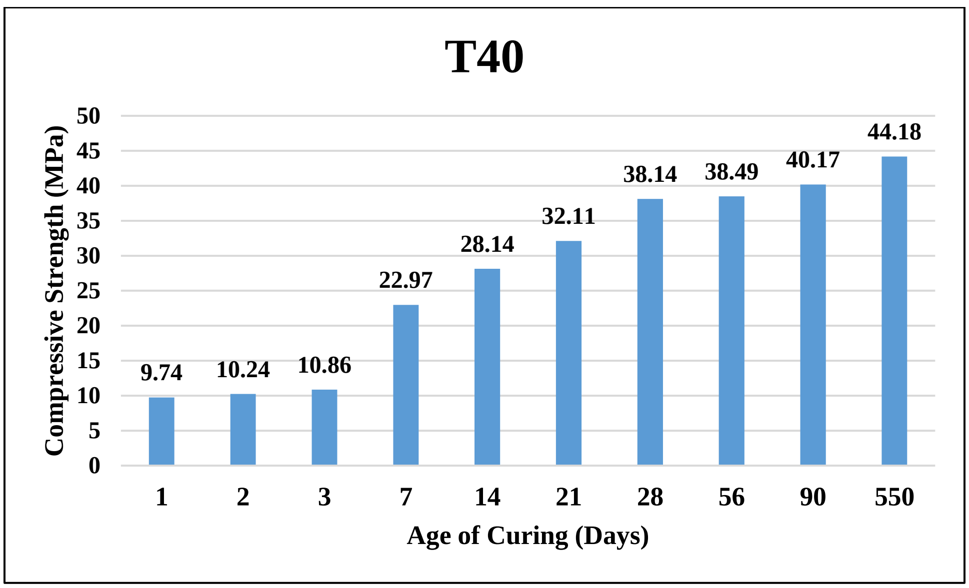

Figure 2. Average compressive strength of T40 mixture.

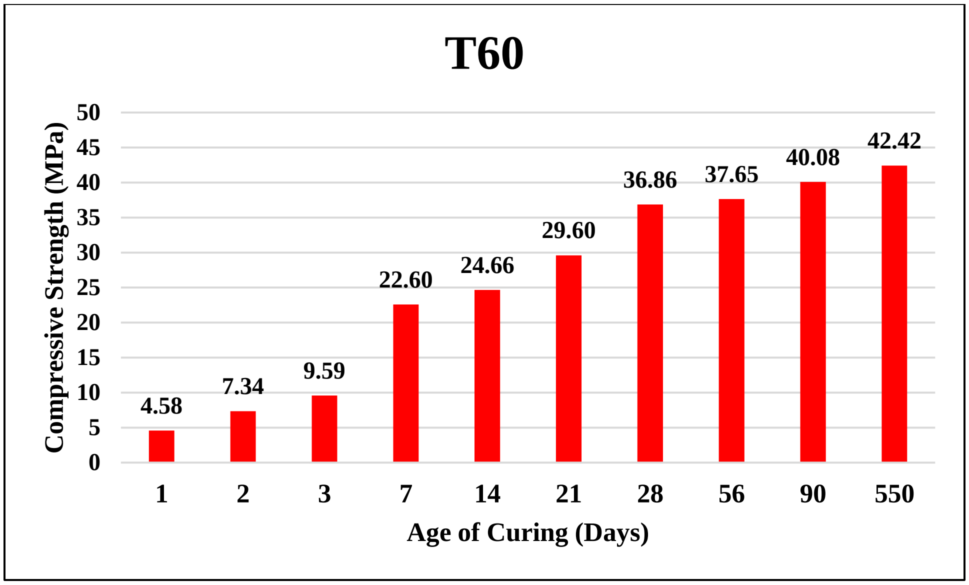

Figure 3. Average compressive strength of T60 mixture.

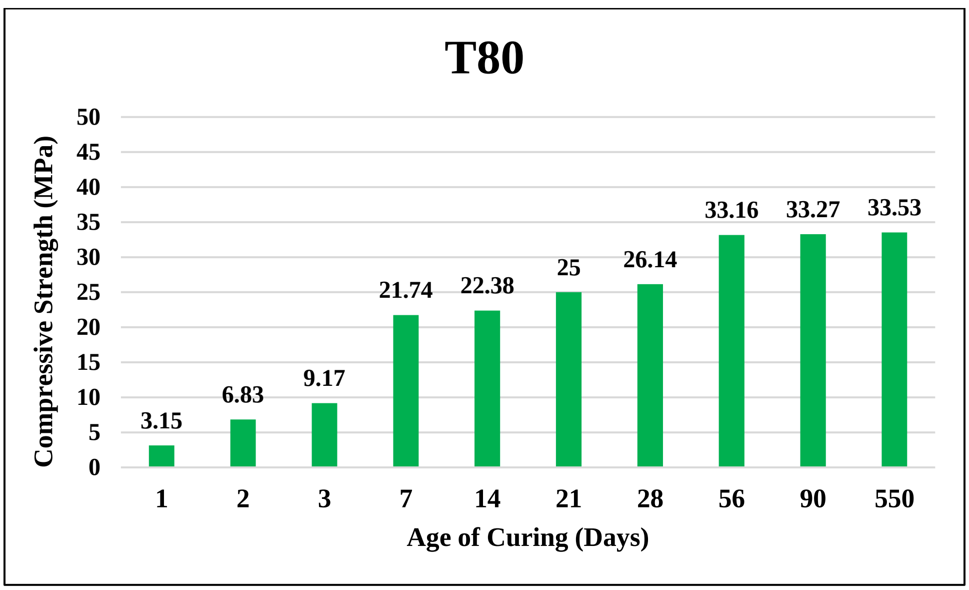

Figure 4. Average compressive strength of T80 mixture.

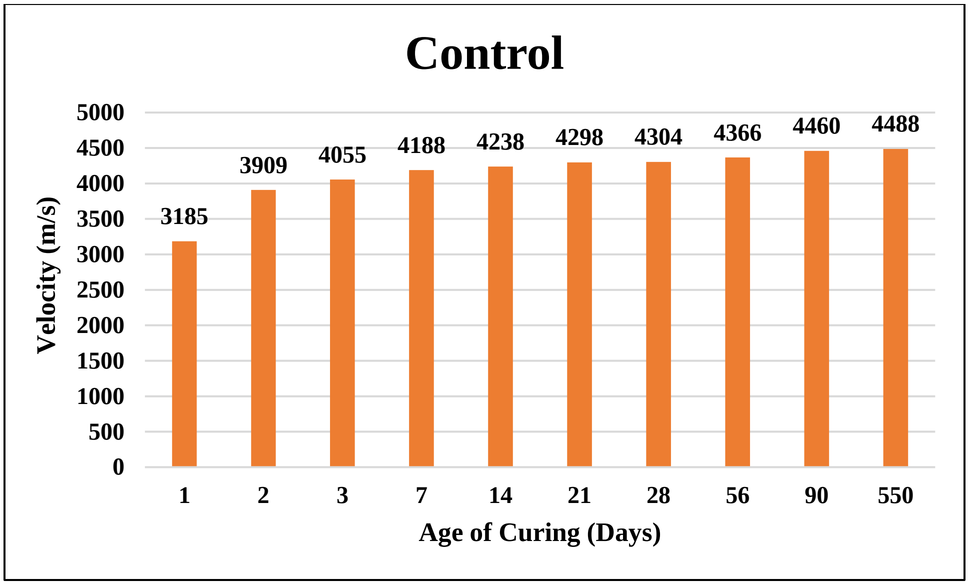

Figure 5. Average UPV of the Control mixture.

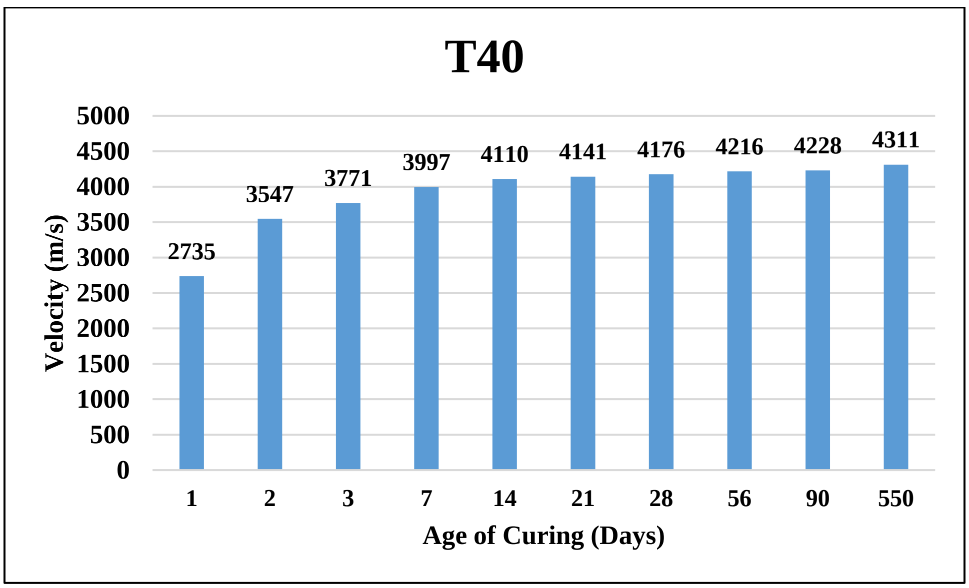

Figure 6. Average UPV of T40 mixture.

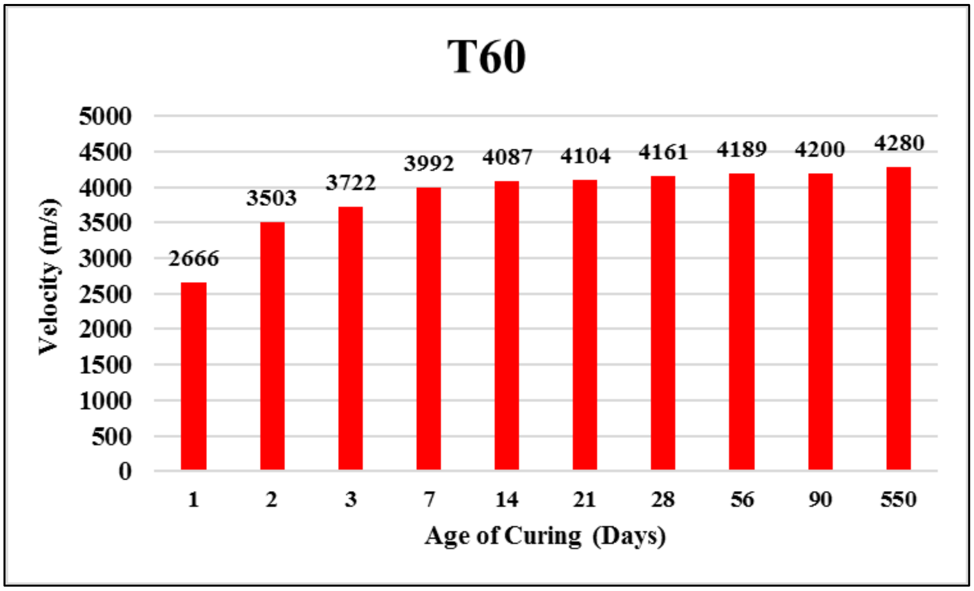

Figure 7. Average UPV of T60 mixture.

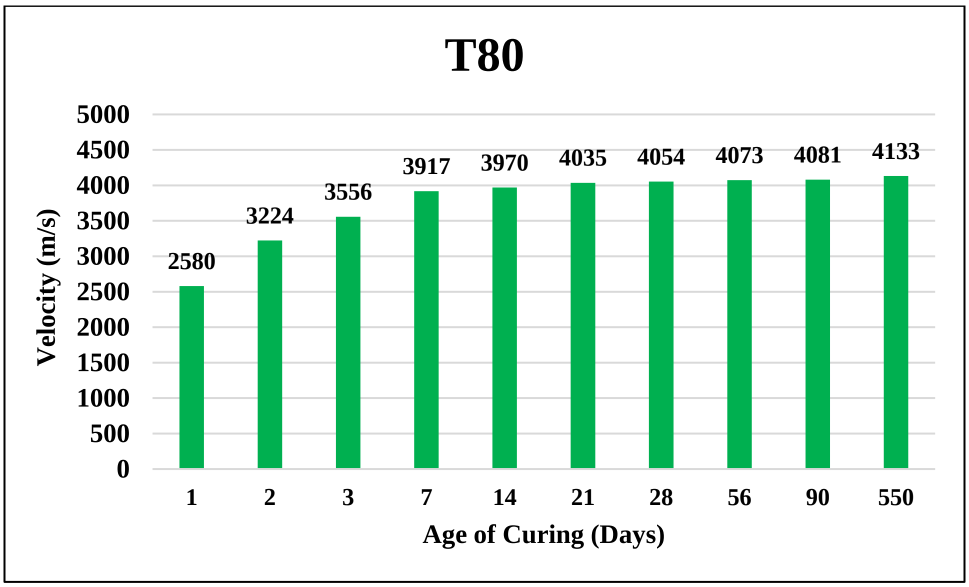

Figure 8. Average UPV of T80 mixture.

Figure 9. Raw materials and mixing of components for the preparation of samples.

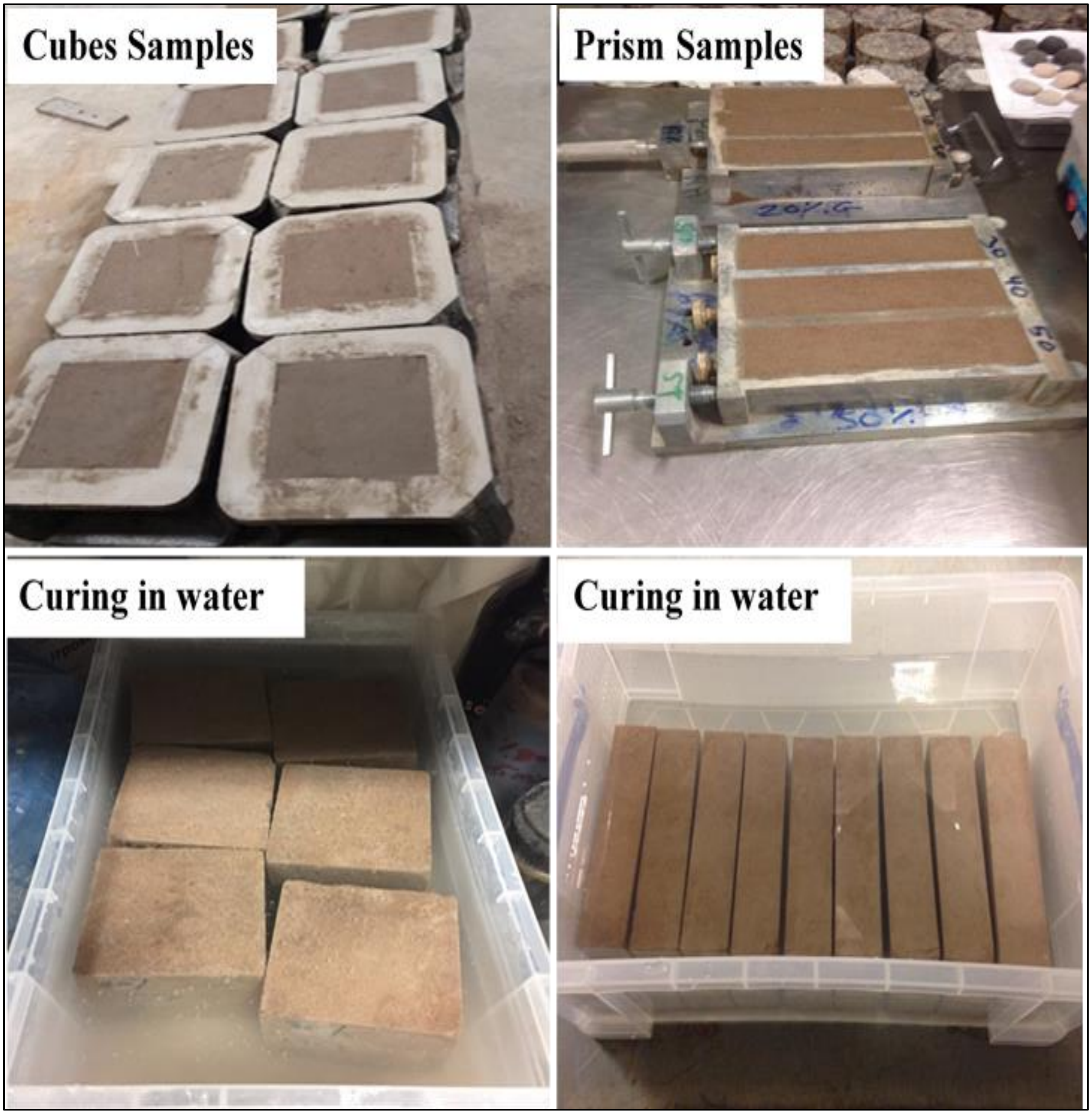

Figure 10. Cubes and prism samples in the moulds and curing in water after demoulding.

Figure 11. State of samples before testing and experimental setups of the UPV and compressive strength tests.

Acknowledgments

The authors would like to acknowledge the financial support provided for this research by Al- Mustaqbal University College, Babylon, Iraq. Additionally, the laboratory support for this research provided by Liverpool John Moors University, UK is gratefully acknowledged.

Competing Interests

None

References

[1] Shubbar, A.A., H. Jafer, M. Abdulredha, Z.S. Al-Khafaji, M.S. Nasr, Z. Al Masoodi, and M. Sadique, *Properties of cement mortar incorporated high volume fraction of GGBFS and CKD from 1 day to 550 days.* Journal of Building Engineering, 2020: p. 101327.

[2] Hasan, Z., M. Nasr, and M. Abed, *Combined Effect of Silica Fume, and Glass and Ceramic Waste on Properties of High Strength Mortar Reinforced with Hybrid Fibers.* Int. Rev. Civ. Eng.(IRECE), 2019. **10**(5).

[3] Kubba, H.Z., M.S. Nasr, N.M. Al-Abdaly, M.K. Dhahir, and W.N. Najim. *Influence of Incinerated and Non-Incinerated waste paper on Properties of Cement Mortar*. in *IOP Conference Series: Materials Science and Engineering*. 2020. IOP Publishing.

[4] Shubbar, A.A., M. Sadique, P. Kot, and W. Atherton, *Future of clay-based construction materials–A review.* Construction and Building Materials, 2019. **210**: p. 172-187.

[5] Shubbar, A.A., M. Sadique, H.K. Shanbara, and K. Hashim, *The Development of a New Low Carbon Binder for Construction as an Alternative to Cement*, in *Advances in Sustainable Construction Materials and Geotechnical Engineering*. 2020, Springer. p. 205-213.

[6] Al-Khafaji, Z.S., Z. Al Masoodi, H. Jafer, A. Dulaimi, and W. Atherton, *The Effect Of Using Fluid Catalytic Cracking Catalyst Residue (FC3R)" As A Cement Replacement In Soft Soil Stabilisation.* International Journal Of Civil Engineering And Technology (IJCIET) Volume, 2018. **9**: p. 522-533.

[7] Nasr, M.S., T.H. Hussain, and W.N. Najim, *Properties of Cement Mortar Containing Biomass Bottom Ash and Sanitary Ceramic Wastes as a Partial Replacement of Cement.* International Journal of Civil Engineering and Technology (IJCIET), 2018. **9**(10): p. 153–165.

[8] Nasr, M.S., Z.A. Hasan, and M.K. Abed, *Mechanical Properties of Cement Mortar Made with Black Tea Waste Ash as a Partial Replacement of Cement.* Engineering and Technology Journal, 2019. **37**(1 Part (c) special): p. 45-48.

[9] Shubbar, A.A., A. Al-Shaer, R.S. AlKizwini, K. Hashim, H. Al Hawesah, and M. Sadique. *Investigating the influence of cement replacement by high volume of GGBS and PFA on the mechanical performance of cement mortar*. in *IOP Conference Series: Materials Science and Engineering*. 2019. IOP Publishing.

[10] Shubbar, A.A., H. Jafer, A. Dulaimi, K. Hashim, W. Atherton, and M. Sadique, *The development of a low carbon binder produced from the ternary blending of cement, ground granulated blast furnace slag and high calcium fly ash: An experimental and statistical approach.* Construction and Building Materials, 2018. **187**: p. 1051-1060.

[11] Shubbar, A., H.M. Jafer, A. Dulaimi, W. Atherton, and A. Al-Rifaie, *The Development of a Low Carbon Cementitious Material Produced from Cement, Ground Granulated Blast Furnace Slag and High Calcium Fly Ash.* International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 2017. **11**(7): p. 905-908.

[12] Nasr, M.S., A.A. Shubbar, Z.A.-A.R. Abed, and M.S. Ibrahim, *Properties of eco-friendly cement mortar contained recycled materials from different sources.* Journal of Building Engineering, 2020: p. 101444.

[13] Shubbar, A.A., D. Al-Jumeily, A.J. Aljaaf, M. Alyafei, M. Sadique, and J. Mustafina. *Investigating the Mechanical and Durability Performance of Cement Mortar Incorporated Modified Fly Ash and Ground Granulated Blast Furnace Slag as Cement Replacement Materials*. in *2019 12th International Conference on Developments in eSystems Engineering (DeSE)*. 2019. IEEE.
[14] BSI, *BS 1881-203: Part 203: Recommendations for measurement of velocity of ultrasonic pulses in concrete*. 1986, BSI: LONDON.
[15] BSI, *Methods of testing cement–Part 1: Determination of strength*. 2005, British Standard Inistitute: London.