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

http://researchonline.ljmu.ac.uk/id/eprint/13257/

LJMU has developed LJMU Research Online for users to access the research output of the University more effectively. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LJMU Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The version presented here may differ from the published version or from the version of the record. Please see the repository URL above for details on accessing the published version and note that access may require a subscription.

For more information please contact researchonline@ljmu.ac.uk

http://researchonline.ljmu.ac.uk/
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 2,3,4, Mohammed Salah Nasr 5, Zainab S. Al-Khafaji 1,5, Hassnen Jafer 1, 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 CO₂ 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 CO₂ into the atmosphere [2-7]. The cement industry contributes about 7% of CO₂ 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.

| Sample | 1 day | 2 days | 3 days | 7 days | 14 days | 21 days | 28 days | 56 days | 90 days | 550 days |
|--------|-------|--------|--------|--------|---------|---------|---------|---------|---------|----------|
| 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   | 40.7    | 44.24    |

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

| Sample | 1 day | 2 days | 3 days | 7 days | 14 days | 21 days | 28 days | 56 days | 90 days | 550 days |
|--------|-------|--------|--------|--------|---------|---------|---------|---------|---------|----------|
| 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.

| Sample | 1 day | 2 days | 3 days | 7 days | 14 days | 21 days | 28 days | 56 days | 90 days | 550 days |
|--------|-------|--------|--------|--------|---------|---------|---------|---------|---------|----------|
| 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 Moores 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, K.H. 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 Institute: London.