Journal of Civil Engineering (IEB), 50 (2) (2022) 59-67

Journal of Civil Engineering IEB

# Strengths of concrete made with white and gray cements

Md. Zakaria Habib, Al-Amin, Syed Ariful Islam, Md. Aman Ullah and Aminoor Islam

*Department of Civil Engineering,*
*Uttara University, Dhaka 1230, Bangladesh*

Received 01 November 2018

**Abstract**

Cement is one of the most important binding materials in civil engineering field. In construction industry cement is having higher demand day by day. Higher consumption of cement in construction industry leads to higher pollution. That's why engineers recommend such cement which will be environmentally friendly, have aesthetic properties, economical and will be sufficient enough to give the desired strength. Generally, there two types of cement available in our local market (gray, white). Recently it is claimed by some of the experts that gray cement concrete gives more strength than white cement concrete. The study mainly aims at justifying the view by comparing the strength of concrete made of white and gray cement. For this purpose, 144 cylinders were cast (4" X 8") in total using mix ratios 1:1.25:2.5 and 1:1.5:3 for 40% and 50% water cement ratios and 7-, 14- and 28-days curing period. By following these criteria 72 cylinders had been cast and crushed both for white cement and gray cement concrete separately. Results show that initial strength gaining rate of white cement concrete is very much higher than gray cement concrete but after 28 days curing period's ultimate compressive strength of gray cement is more by 156 psi (minimum), 205 psi (maximum) and 181 psi on an average where tensile strength by 48 psi (minimum), 91 psi (maximum) and 75 psi on an average than of white cement concrete.

© 2022 The Institution of Engineers, Bangladesh. All rights reserved.

*Keywords:* Gray cement, white cement, concrete, compressive strength, tensile splitting strength.

## 1. Introduction

White Portland cement (WPC) has similar bonding characteristics as gray Portland cement. WPC has also higher performance due to use of high-quality materials and control process in its production. WPC is generally used in the production of non-structural members, which are built for decorative and aesthetical purposes. White concrete produced with WPC has higher compressive strength and reaches its ultimate compressive strength faster than normal gray Portland cement [Temiz et al., 2013]. Decoratively, white cement concrete can be used to

make terrazzo, architectural fixtures, and sculptures or exterior cladding. In this way, decorative concrete can be cast with the flexibility of concrete, letting the imagination dictate the size and shape, while at the same time mimicking more convincingly the appearance of natural stone. Practically, white cement concrete can be used to increase safety or energy efficiency. Because it is highly reflective, it can either highlight median barriers or increase the light in large industrial building. Alternatively, the reflectance can be used to maintain the same level of light in a room with fewer light fixtures or can be used to reduce the costs of heating/cooling [Gillette, 2004]. Finally, white cement concrete can be used structurally, in the same manner as gray cement concrete, with the added drama of color. Unlike the dry shake or exterior cladding, the color is integral with the structure and less maintenance is required of the surface if there is chipping or cracking exposing the interior concrete [Gillette, 2004].

## 2. Problem statement

One significant barrier, which often results in traditional gray concrete, being chosen instead of white concrete, is the perception among decision-makers that white concrete produces less strength and durability than gray concrete. However, the chemical composition of white cement from white Portland cement made in Bangladesh is ideally suited for the production of concrete with high strength and durability [Bye, 1999]. On this background, an experimental program was conducted to determine the compressive and tensile strength of concrete made with white and gray cement. For this purpose, two mix ratio (1:1.25:2.5 and 1:1.5:3 respectively) and two water cement ratio (0.40 and 0.45) were used and a total number of 144 cylinders were cast and crushed equally both for gray and white concretes. This research also covers the determination of tensile and compressive strength comparisons of white and gray cement concrete separately. Mainly this research aimed at determining or comparing the strength (tensile and compressive) of concrete made of white and gray cement. The objectives of this research are:

- To compare the compressive strength of concrete made with white cement with that of gray cement.
- To compare the tensile strength of concrete made with white cement with that of gray cement.

## 3. Cement

Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry or with sand and gravel aggregates to produce concrete [Cement, 2018].

Fig. 1. Gray cement [Water Cement Ratio, 2018]

Fig. 2. White cement [White Cement, 2018]

White Portland cement is a white colored hydraulic bonding material produced by grinding of white clinker, obtained by white clay and limestone and calcium sulfate ($CaSO_4.2H_2O$) [Temiz et al., 2013]. To achieve architectural and aesthetic projects that makes cities more beautiful. White cement is a perfect solution. Based on advanced technology, they can produce white precast concrete for urban furniture, flooring or structural elements [Greener et al., 2000].

Table 1
Gray and white cement compositions [Temiz et al., 2013]

| Cement | | Clinker | | Cement | | Clinker | |
|---|---|---|---|---|---|---|---|
| | Gray % | Black % | White % | | Gray % | Black % | White |
| $SiO_2$ | 19-23 | 21.7 | 23.8 | LSF | 90-98 | 98.4 | 97.2 |
| $Al_2O_3$ | 3-7.0 | 5.3 | 5 | LCF | - | 96.2 | 93.8 |
| $Fe_2O_3$ | 1.5-4.5 | 2.6 | 0.2 | S/R | 2-4 | 2.7 | 4.6 |
| CaO | 63-67 | 67.7 | 70.8 | A/F | 1-4 | 2 | 25 |
| MgO | 0.5-2.5 | 1.3 | 0.08 | $C_3S$ | - | 65.4 | 59.4 |
| $K_2O$ | 0.1-1.2 | 0.5 | 0.03 | $C_2S$ | - | 12.9 | 23.5 |
| $Na_2O$ | 0.07-0.4 | 0.2 | 0.03 | $C_3A$ | - | 9.6 | 12.9 |
| $SO_3$ | 2.5-3.5 | 0.7 | 0.06 | $C_4AF$ | - | 7.9 | 0.6 |
| LOI | 1-3.0 | - | - | | | | |
| IR | 0.3-1.5 | - | - | | | | |
| Free Lime | 0.5-1.5 | 1.5 | 2.5 | | | | |

White Cement and Gray Cement are usually compared on five terms which are as follows:

- *Raw Material:* Gray color of the cement is mainly due to high content of oxides of iron, manganese and chromium which are present in limited amount in white cement.
- *Strength and Setting Time:* Its setting behavior and strength development are essentially the same as those expected in gray cement.
- *Fineness:* White cement is usually finer than gray cement and thus, gives better finishing.
- *Cost:* Due to more complex manufacturing process of white cement, it is expensive than gray cement. In India, white cement is usually around Rs. 20 per kg costlier than gray cement.
- *Uses:* White cement due to its whiteness is mainly used for architectural beauty, interior and exterior decorations, floorings, ornamental concrete products such as idols while gray cement are mostly used for construction purposes [https://www.quora.com, 2018].

## 4. Methodology

The experimental program was designed to compare the compressive strength and tensile strength of white cement and gray cement. The research also included the effect of water cement ratio and mix ratio on concrete. The first step done in the experimental study was identifying the control variables. The variables which remain unchanged throughout the experiment are called independent variables.

The variables which are changed throughout the experiment are called dependent variables. The independent variables of the experiments are as follows: Mix ratio, Water cement ratio and Curing age. The dependent variables of the experiments are cylinder compressive strength. The following material was used to perform this research.

### *4.1 Cement*

Properties of gray cement and white cement are given in the following table.

Table 2
Properties of cement

| Name of the test | Gray cement | White cement |
|---|---|---|
| Normal Consistency | 28.5% | 28% |
| Initial Setting Time | 85 minutes | 65 minutes |
| Final setting Time | 170 minutes | 120 minutes |

### *4.2 Coarse aggregates and fine aggregate*

Locally available crushed stone and natural Sylhet sand were used in the overall study. The physical properties are given in the following table.

Table 3
Properties of coarse and fine aggregate

| Properties | Coarse aggregate | Fine aggregate |
|---|---|---|
| Fineness Modulus (FM) | 3.45 | 2.95 |
| Specific Gravity | - | 2.58 |
| Bulk Specific Gravity (OD) | 2.62 | - |
| Apparent Specific Gravity (SSD) | 2.64 | - |
| Unit Weight | 1541 kg/m$^3$ | 1495 kg/m$^3$ |
| Absorption Capacity | 0.4% | 1.3 % |

Table 4
Slump value of concrete

| Mix ratio | W/C | Slump | |
|---|---|---|---|
| | | Gray cement | White cement |
| 1:1.25:2.5 | 0.40 | 3 in. | 1.5 in. |
| | 0.45 | 5.8 in. | 4.5 in. |
| 1:1.5:3 | 0.40 | 2 in. | 1 in. |
| | 0.45 | 5 in. | 4 in. |

Table 5
Research plan

| Mix ratio | Water cement ratio | Sample details | | |
|---|---|---|---|---|
| | | Tension White + Gray | Compression White + Gray | Total |
| 1:1.25:2.5 | 0.40 | 9+9=18 nos | 9+9=18 nos | 36 nos |
| | 0.45 | 9+9=18 nos | 9+9=18 nos | 36 nos |
| 1:1.5:3 | 0.40 | 9+9=18 nos | 9+9=18 nos | 36 nos |
| | 0.45 | 9+9=18 nos | 9+9=18 nos | 36 nos |
| Total no of specimen | | | | 144 nos |

A total number of 144 cylinders (D-4 in. × H-8 in.) were cast for mix ratio 1:1.25:2.5 and 1:1.5:3 (by volume), water cement ratio 0.40 and 0.45 (by weight) and for curing age 7 days,

14 days, and 28 days. In which 72 nos. cylinders were crushed for Tensile and Compressive Strength of Gray Cement and another 72 nos. cylinder were crushed for Tensile and Compressive Strength of White Cement.

All batches of cylinders were cast inside the laboratory. The mixing and casting are conformed to ASTM [1945] C192. Each batch was used to cast 12 standard sized cylinders specimens were cast in three layers and each layer was compacted by using a temping rod of size 16mm in diameter up to 25 blows. After compacting the top of the specimen was finished smoothly with the help of a trowel and was then exposed to actual environmental condition. The specimen was remolded after 24 hrs. and then immersed into water.

## 5. Results and discussion

In this section result of the study has been summarized considering the variables considering the variables stated previous. After curing of all cylinder specimens for desired periods, each was crushed both for compressive and tensile strength in UTM (Universal Testing Machine). The graphical representation of results are as follows

### *5.1 Compressive strength*

It is seen in Figure 3 that, the compressive strength gaining rate of white cement is much more than gray cement initially but after 28 days curing period strength obtained by gray cement concrete is more by almost 205 psi than white cement concrete. After 7 and 14 days of Curing period white cement concrete gain almost 82-84 % and 95-97 % strength where for gray cement is 64-66 % and 88-90 % respectively.

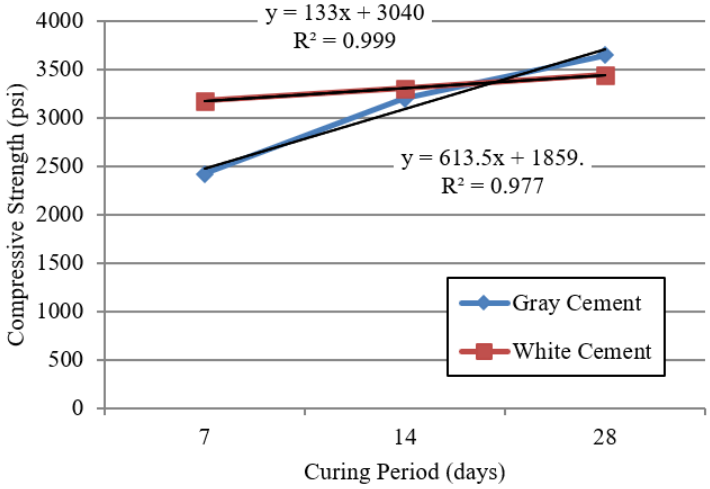


Fig. 3. Compressive strength comparison of concrete made with gray and white cement. [W/C: 0.40 and Mix ratio: 1:1.25:2.5].

Figure 4 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 15 days of concrete age white concrete gain almost 97% strength where for gray it is seen about 90% of total strength.

Figure 5 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 15 days concrete age white concrete gain almost 97% strength where for gray it is seen about 90% of total strength.

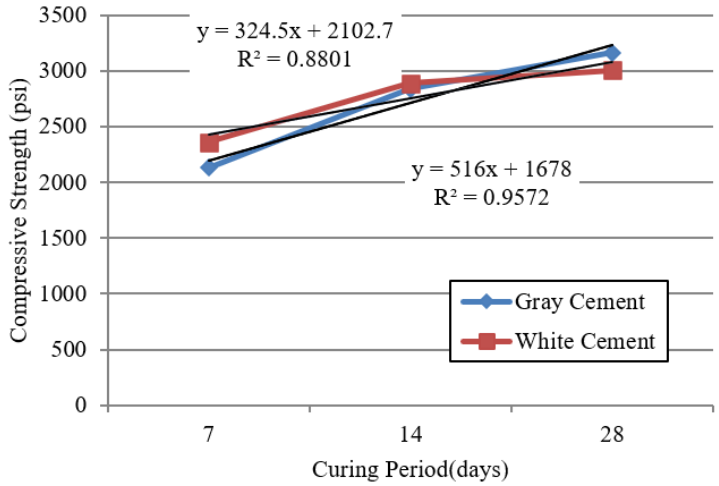


Fig. 4. Compressive strength of concrete made with gray and white cement [W/C: 0.45 Mix ratio: 1:1.25:2.5]

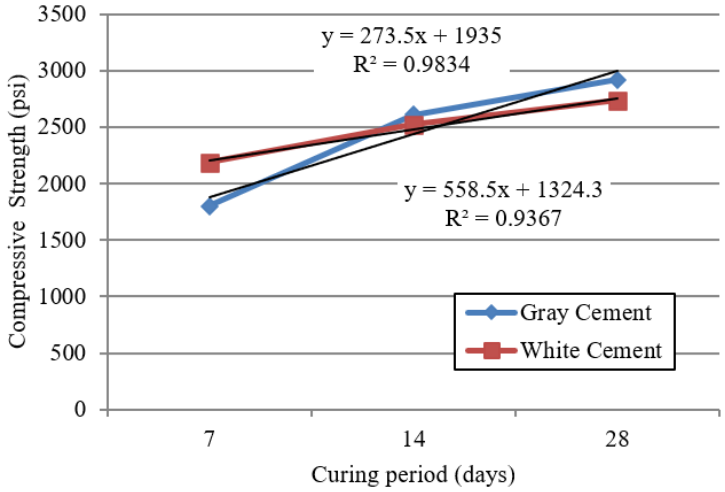


Fig. 5. Compressive Strength of concrete made with gray and white cement. [W/C : 0.40 Mix ratio: 1:1.5:3]

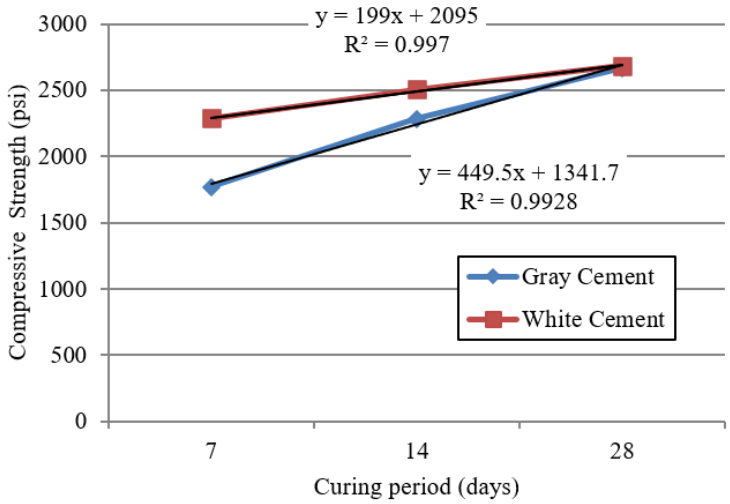


Fig. 6. Compressive Strength of concrete made with gray and white cement [W/C: 0.45 Mix ratio: 1:1.5:3]

Figure 6 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 15 days of concrete age white concrete gain almost 97% strength where for gray it is seen about 90% of total strength.

### *5.2 Tensile strength*

It is seen, although initial tensile strength of white cement concrete is more but after a certain period the overlap each other and finally gray cement concrete obtain higher strength (Figure 7).

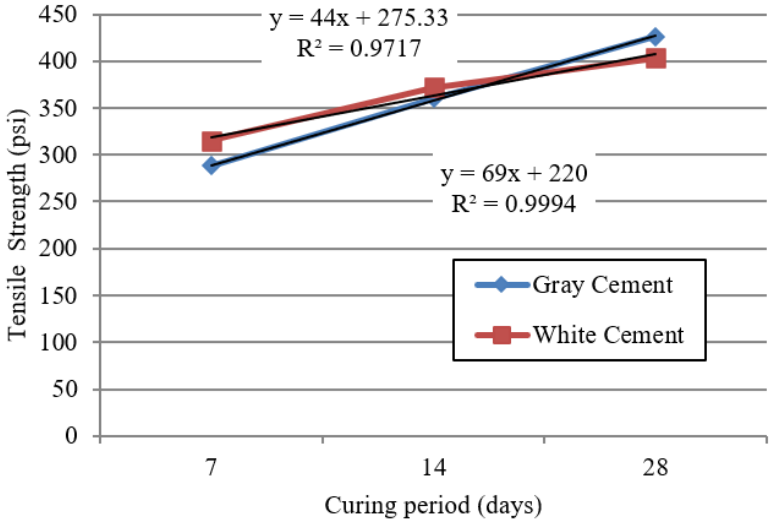


Fig. 7. Tensile Strength of concrete made with gray and white cement [W/C: 0.40 Mix ratio: 1:1.25:2.5]

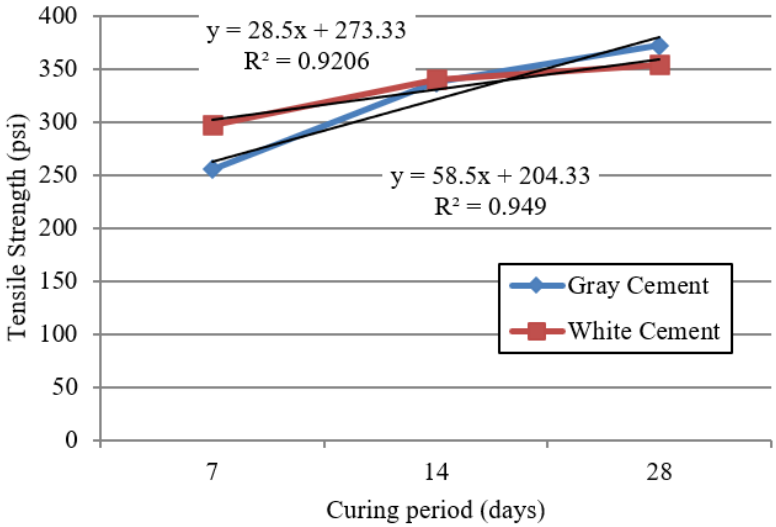


Fig. 8. Tensile Strength of concrete made with gray and white cement [W/C: 0.45 Mix ratio: 1:1.25:2.5]

Figure 8 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 14 days of curing age white concrete gain almost 97% strength where for gray it's seen about 90% of total strength.

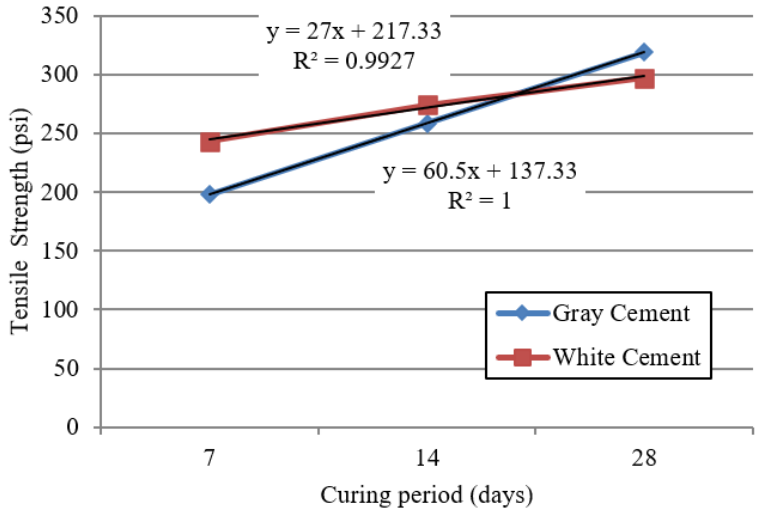


Fig. 9. Tensile Strength of concrete made with gray and white cement [W/C: 0.40 Mix ratio: 1:1.5:3]

Figure 9 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 15 days of concrete age white concrete gain almost 97% strength where for gray it is seen about 90% of total strength.

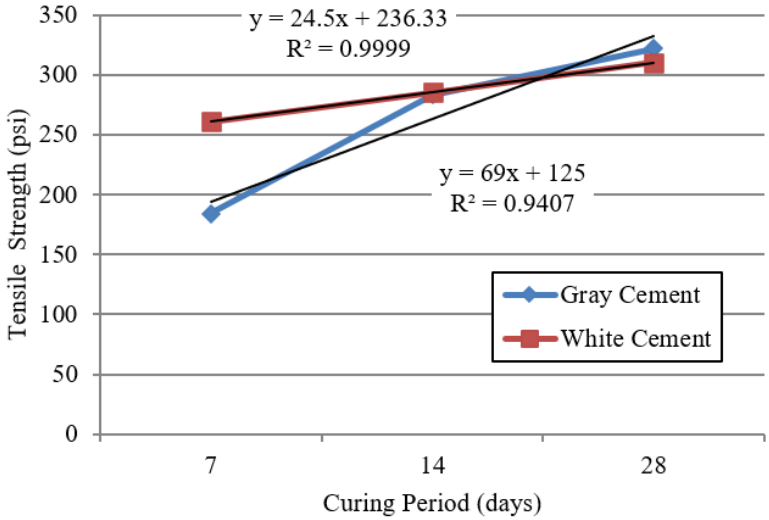


Fig. 10. Tensile Strength of concrete made with gray and white cement [W/C: 0.45 Mix ratio: 1:1.5:3]

Figure 10 shows that initial strength of white cement concrete is higher than the gray cement concrete but after a certain curing period gray concrete possess higher strength than white concrete. Within 15 days of concrete age white concrete gain almost 97% strength where for gray it's seen about 90% of total strength.

## 6. Conclusions

The following conclusions are made for the current study:

- Initial strength gaining rate of gray cement concrete is very much lower than white cement concrete.
- The ultimate compressive strength of gray cement concrete is more by 156 psi (minimum), 205 psi (maximum) and 181 psi on an average where tensile strength by 48

psi (minimum), 91 psi (maximum) and 75 psi on an average than of white cement concrete.

- After 7 days of curing time gray cement obtained about 65-70% strength whereas white cement obtains 80-85% which much more than of gray cement.
- White cement is better for early strength as its initial strength of concrete is more than gray cement.
- The tensile strength of concrete is almost 12% of its compressive strength both for white cement and gray cement.

**References**

Bye. G. C. (1999). "Portland cement: Composition, production and properties". Thomas Telford Publishing, London, Vol. 5, pp. 164-165.

Camilleri, J. (2008). "The physical properties of accelerated Portland cement for endodontic use". International Endodontic Journal, Vol. 41, pp. 151–157. doi:10.1111/j.1365-2591.2007.01330.x.

Cassar, L., Pepe, C., Tognon, G., Guerrini, G. L. and Amadelli R. (2003). "White cement for architectural concrete, possessing photocatalytic properties". International Congress on the Chemistry of Cement.

Cement. Retrieved from https://en.wikipedia.org/wiki/Cement, August 05 2018.Cement.html, August 06 2018.

Gillette, M. White cement concrete. University of California, Berkley, 30th March 2004.

Gray Cement. Retrieve from http://www.dyckerhoff.com/online/en/Home/Gray

Greener, J., Peemoeller, H., Choi, C., Holly, R. Reardon, E. J., Hansson, C. M. and Pintar, M. M. (2000). "Monitoring of Hydration of White Cement Paste with Proton NMR Spin–Spin Relaxation". Journal of the American Ceramic Society, Vol. 83, No. 3, pp. 623-627.

Hoque, M., F., Gani, M., O. and Hoque, M., N. (2014). "A Study on Strength Properties of White-Cement". International Journal of Business, Social and Scientific Research, Vol. 01, pp. 61-64.

Neville, A. M. (1996). "Properties of Concrete", Fourth Edition, John Wiley and Sons, New York, NY.

Portland Cement. Retrieved from https://theconstructor.org/building/manufacture-of-cement/13709/, August 08 2018.

Temiz, H., Kose, M. M. and Genc, H. M. (2013). "Mechanical Behavior of White Concrete". TEM Journal, Vol. 2.

Water Cement Ratio: The Importance of Water/Cement Ratio. Retrieved from, https://civilsnapshot. com/different-types-cement/, September 10 2018.

White Cement. Retrieved from http://surfcivil.blogspot.com/2015/04/advantages-and-disadvantages-of-white.html, August 05 2018.