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Effect of Bentonite Blend on the Compressive Strength of Various Concrete Mixes

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Abstract— **Bentonite as blend with ordinary Portland cement is a review of the use of supplementary cementitious materials in concrete. Environmental concerns both in terms of damages caused by the extraction of raw material and CO2 emissions during cement manufacture, have brought about pressures to reduce cement consumption by use of supplementary materials. In addressing environmental problems and economic advantages, mixtures of Portland cement (PC) and pozzolan are very commonly used in concrete production [Sabir et al., 2001]. This study is therefore to investigate the range of ordinary Portland cement – bentonite mix proportion that can be found useful for particular use in the construction industry.**

I. INTRODUCTION

Revolutionary developments relating to novel materials for concrete production and to modifications and improvements in the behaviour of traditional materials have been taking place in the past two decades. These developments have been facilitated by increased knowledge of the atomic and molecular structure of materials, studies of long-term failures, the development of more powerful instrumentation and monitoring techniques, decreases in the cost-effectiveness of traditional materials, and the need for stronger and better performing materials suitable for larger structures and longer spans, as well as for increased ductility. (Nawy, E. G., 1996)

The construction industry has taken considerable strides forward over the last two or three decades with regard to trials in the use of one or another cementitious materials generally identified as pozzolans, for the compounding of various cement based products. This have not only resulted in improving the compressive strength value attained thereby but also in qualities like ability to set and harden under water. Among these coal fly-ash, blast furnace slag, rice hull ash, silica fume, or metakaolin are the most common ones. Other like gypsum, gypsum fines, Portland cement, cement kiln dust, lime dust, stone dust, and calcined clay are also in use.

Due to economic and environmental concerns, different methods of making cement products are being considered. One method to achieve the goal of reducing carbon dioxide emissions and greenhouse gases is to formulate cements using a lower portion of calcinated material, thereby reducing carbon dioxide emissions per unit of product. Another approach is that of including a lower percentage of cement and /or gypsum than it is common with standard cement or gypsum and to ensure an increased compressive strength and/or flexural strength is yet attained thereby. This as one which is durable, and suitable for all types of applications, also benefits the environment. Additionally, a need exists for improved cement and gypsum products that permit the use of less expensive aggregates to reduce the cost of the cement product.

Bentonite is a form of calcined clay (i.e. clay that has gone through heat process to be in its powder form) that consists of a primary mineral called montmorillonite which gives it its properties. Calcined clay seems to have the greatest overall potential as alternative pozzolanic material for concrete due to its availability in large quanta and the relatively cheap price. Though the mineralogy of clays varies a lot, which may influence the reactivity, its interaction with CSH gel formed during ordinary Portland cement has been found beneficial to the final form of the hardened concrete. The benefit of it being used as partial replacement of a portion of the ordinary Portland cement has been found not only on strength improvement, but more on durability enhancement.(Detwiler et al., 2001)

II. LITERATURE REVIEW

The definition of natural pozzolans according to ASTM Standard C618 is siliceous or siliceous and aluminous materials, which in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. Within the building industry, the term "pozzolan" covers all the materials which react with lime and water giving calcium silicate and aluminate hydrates. All pozzolans have to be rich in reactive silica or alumina plus silica [Bensted and Barnes, 2002]. According to ASTM standard C618 the requirements as to chemical composition of natural pozzolan are approximately 70 % in contents of silicon dioxide (SiO_2), aluminium oxide (Al_2O) and iron oxide (Fe_2O_3) of which is present in bentonite structure. The loss on ignition is required to be a maximum of 10 %, according to the same standard. The acidic and amphoteric oxides (silica, alumina and ferric oxide) contents vary widely from one pozzolan to another. Silica is a major component in natural and processed pozzolans.

Pozzolans are classified into natural materials and artificial. Artificial ones are mostly industrial by-products. Bentonite needs to be calcined from its crystalline form for better performance. According to Souza and Molin (2005), calcination (also referred to as calcining) is the thermal treatment process applied to ores and other solid materials in

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order to bring about a thermal decomposition, phase transition, or removal of a volatile fraction. The calcination process normally takes place at temperatures below the melting point of the product materials. Calcination is to be distinguished from roasting, in which more complex gas-solid reactions take place between the furnace atmosphere and the solids.

Clay is a fine grained material consisting mainly of aluminum silicates that occur naturally in soils and sedimentary rocks. Clays are rarely found separately and are usually mixed with other clays and with microscopic crystals of carbonates, feldspars, micas and quarts. Clay minerals are divided into four major groups: kaolinite, montmorillonite/smectite, illite and chlorite groups. The compositions of clay minerals depend on geographic area and the bedrock, and vary a lot all over the world.

Clay may be present in aggregates in the form of surface coatings which interfere with the bond between aggregate and the cement paste. Good bond is essential to ensure a satisfactory strength and durability of concrete. Other fine materials which can be present in aggregate, silt and crusher dust can be removed by washing the aggregate.

III. MATERIALS USED

1. Cement

Cement is one the major component in the manufacturing process of concrete. It has the property to stick to any other raw material added in the preparation process of concrete, especially when comes in contact with water and hence produces a good paste. Here, OPC 53 grade cement is used whose properties are shown below.

2. Fine Aggregate

Fine aggregate is first graded to decide the zone to which it belongs to. Generally, there are four categories of fine aggregate Zone-I, Zone-II, Zone-III & Zone-IV. In this work, sand of zone-II is chosen whose properties were given below. Generally, fine aggregate is passed through 4.75 mm sieve.

3. Coarse aggregate

Coarse aggregate is another fundamental raw material which gives strength, hardness and increases the volume of the concrete. Here, coarse aggregate of size 20 mm and angular crushed shape is chosen.

3. Bentonite

The bentonite used was a sodium type, manufactured by Changsha May Shine Chemical Co., Ltd [Province: Hunan, China] but purchased from Lagos.

4. Water

Water plays a major role in concrete mixing in that it starts the reaction between the ordinary Portland cement, rice husk ash and the aggregates.

It also helps in the hydration of the mixture. In this research, the water used was that of National Water and Sewerage Cooperation which is safe drinking water as specified in the standard (EN 1008, 1997).

IV. RESULTS & DISCUSSIONS

EXPERIMENTAL TEST RESULTS:

3.Slump Test:

As bentonite was introduced to the mixes, there was reduction in slump value with an exception in the 1:2:4 mix, whose workability increased instead [as opposed to expected results]. This behaviour may be as a result of environmental conditions such as humidity that occurred during casting, or other aggregate properties.

Bentonite, a clay material swells and absorbs water thereby increases the rate of hydration and reduces workability as seen in majority of the mixes except the 1:2:4 mix at 10%, which recorded a deviation in both water/cement ratios. No slump test was carried out for the bentonite control mix due to its sticky or plastic nature; therefore, bentonite control mix had a zero slump value. Conclusively, since bentonite used was swelling clay, it increased the hydration rate of the mixes and reduced the setting time.

Slump values for all mixes shows 1:3:6 mix has the lowest workability, followed by 1:2:4 mix and then 1:1.5:3 mix was the most workable except for 30% bentonite blend which deviated.

Hence, it could be inferred that when workability is been considered, bentonite may be used comfortably in the 1:1.5:3 and 1:2:4 mixes up to about 20% using a water/cement ratio=0.8.

Conclusively, slump shows workability (ease of concrete placement and to attain a highly dense structure). Predominantly, single size with two or three close particle sizes have made any denseness impossible for the placing. Slump value may not be used as a guide for strength development prospects, hence, reliance will be on the CSH gel or inherent formation status and the curing conditions exposed to.

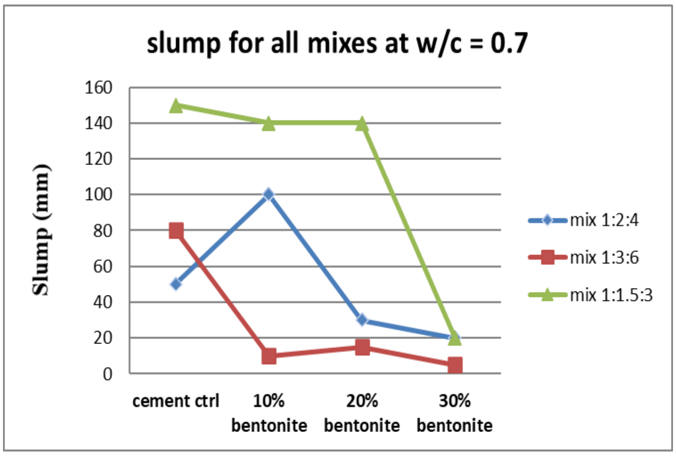

Fig 1.Slump of concrete at w/c ratio 0.7 for all concrete mixes

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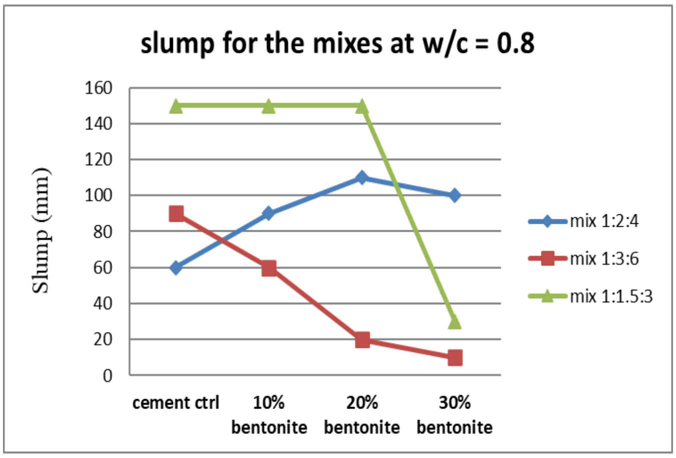

Fig 2.Slump of concrete at w/c ratio 0.8 for all concrete mixes

Compressive strength test results:

Compressive strength of same mixes but different water-cement ratios:

A) Cement control variant:

The three cement control mixes with water-cement ratio of 0.7 had the highest compressive strength at twenty eight days except for the 1:3:6 mix, whose reduction in strength may be due to internal cracks that resulted when detaching concrete cubes from mould.

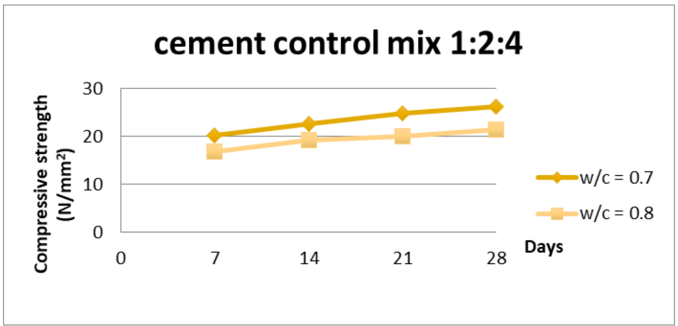

Fig 3. Cement control mix 1:2:4

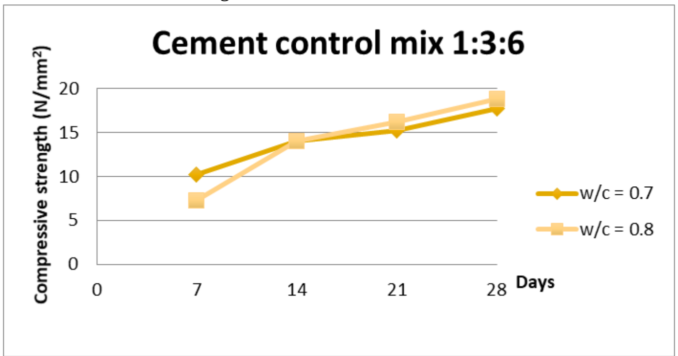

Fig 4. Cement control mix 1:3:6

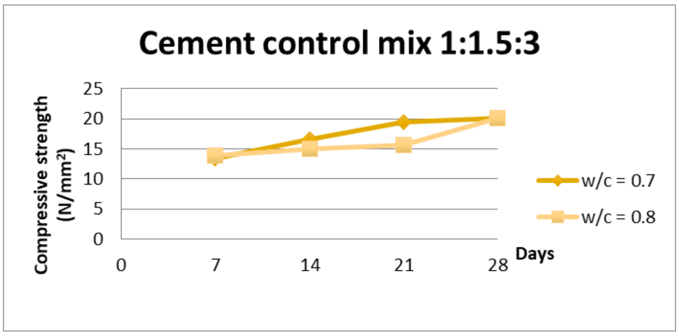

Fig 5. Cement control mix 1:1.5:3

B) Variant with 10% bentonite blend:

In summary, we can see that on comparing the three mixes, under normal conditions, water- cement ratio 0.8 is the optimum variant that favours compressive strength, except for in the 1:2:4 mix which shows a deviation in ultimate strength at 14-days curing age, it may conservatively be considered to be the optimal water- cement variant in all three mixes. The reason for the behaviour in figs. 4.1.4N and 4.1.4O is however unclear.

The optimal mix is 1:1.5:3 at water-cement ratio 0.8 because it possesses the highest ultimate strength values at 28days.

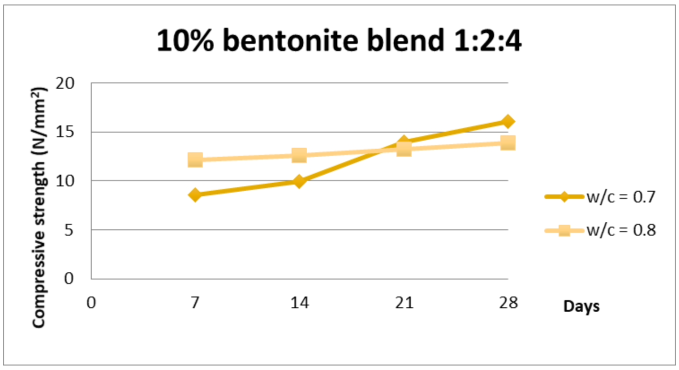

Fig 6. 10% bentonite blend 1:2:4

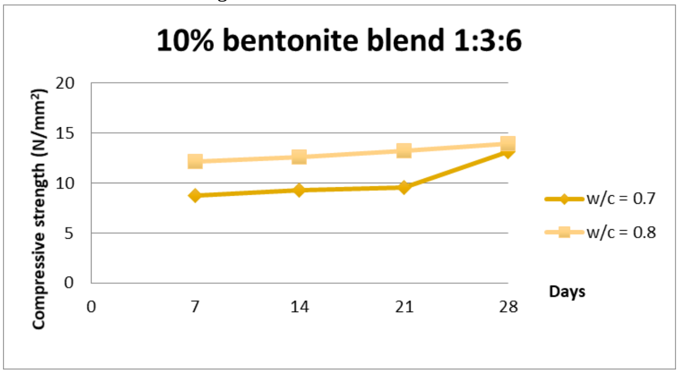

Fig 7. 10% bentonite blend 1:3:6

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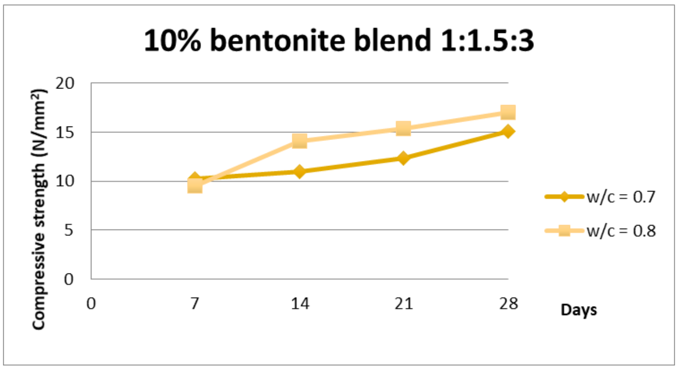

Fig 8. 10% bentonite blend 1:1.5:3

C) Variant with 20% bentonite blend:

In summary, for the three mixes, the water-cement ratio 0.7 had the highest compressive strength except for the 1:3:6 mix which has more pore spaces/voids in its structure, leading to low compressive strength.

It can thus be concluded that, using 20% bentonite blend, the mix 1:2:4 at water- cement ratio 0.7 is the optimal mix because it has the highest ultimate compressive strength at 28days.

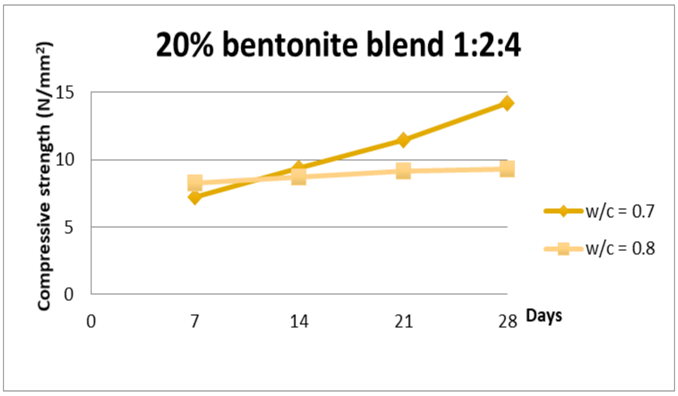

Fig 9. 20% bentonite blend 1:2:4

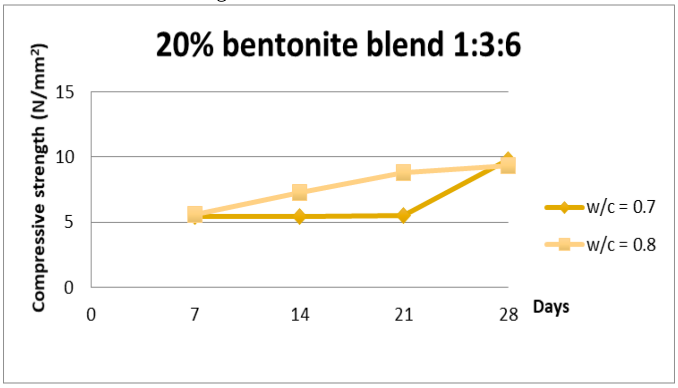

Fig 10. 20% bentonite blend 1:3:6

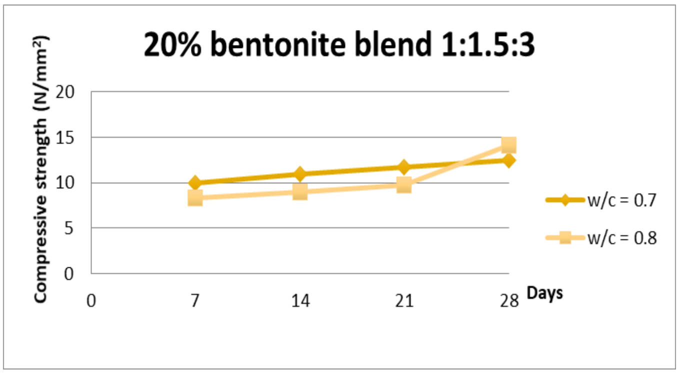

Fig 11. 20% bentonite blend 1:1.5:3

D) Variant with 30% bentonite blend:

At 30% bentonite blend, the optimal mix is 1:2:4 mix at water-cement ratio 0.7, which has the highest ultimate compressive strength at 28days.

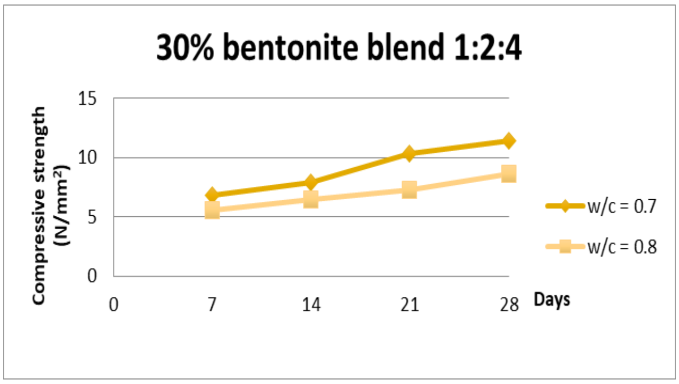

Fig 12. 30% bentonite blend 1:2:4

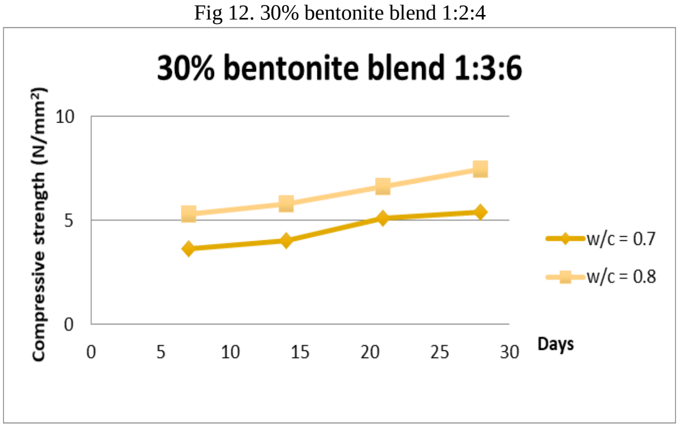

Fig 13. 30% bentonite blend 1:3:6

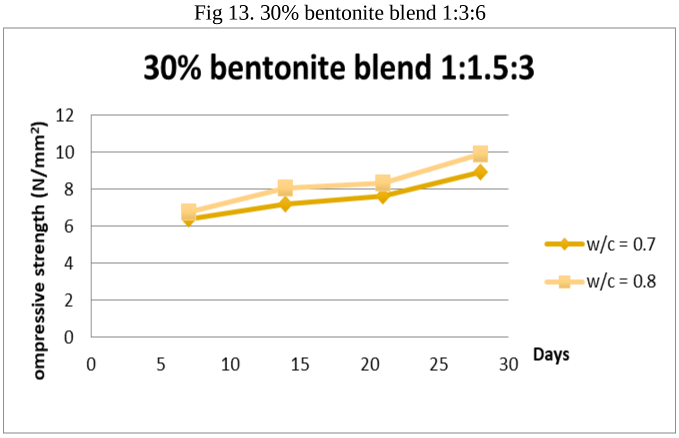

Fig 14. 30% bentonite blend 1:1.5:3

V. CONCLUSIONS

From the study carried out, the following conclusions can be made;

- The 1:2:4 mix appears to be apparently better on the basis of having the highest compressive strength value all through this experiment. This can be attributed to errors from batching systems (errors that occurred when adding water) and the unexplainable effect of using single sized aggregate and other general factors resulting from manual mixing methods employed in mixing. The high compressive strength values of the 1:2:4 mix can also be attributed to large volume of coarse aggregate, which mass to provide resistance to shearing.
- Based on the discussion of results in the previous chapters that clay content, when present in any concrete mix has detrimental effect to the concrete compressive strength, the result shows that bentonite blend can be used in-place of ordinary Portland cement if not more than 20% substitution to give an acceptable and required compressive strength. It can also be inferred that bentonite control mix cannot be used for construction work due to its relatively high hydration properties, low compressive strength and shrinkage. These properties are as a result of the fact that clay materials have ability to store water in their pores for a long time, and this water retention capacity does not favour compressive strength as it causes concrete to fail easily when subjected to compressive or shear forces.
- The 1:3:6 mix has the lowest compressive strength due to the presence of voids in the internal structure of the concrete cubes, filled by the bentonite-cement gel (since bentonite swells when mixed with water), which expands in the voids, causing reduction in the cohesion between aggregates. The low values of compressive strength could also have resulted from inadequate compaction and reduced workability due to a higher aggregate-cement ratio.
- According to standard (when using ordinary Portland cement), the 1:1.5:3 mix should have the highest compressive strength for the cement control mix but the high water-cement ratio used affected the compressive strength. Other factors that affected the general concrete cube strength were the non-uniform compaction, use of sub-standard mixing tools, and single sized coarse aggregate used (angular). Therefore, we can use the 1:1.5:3 mix with better aggregate grading and adequate water-cement ratio, since it has closer compressive strength values to that of the 1:2:4 mix.
- Concrete compressive strength achieved in this thesis is lesser than that required by the British Standard code for materials and construction.
- Bentonite blend not more than 20% substitution will provide desired result as a blend with ordinary Portland cement although early strength may be very low but with time, considerable values of compressive strength will be achieved. There is the case that higher durability and less pollution to the environment from cement production may be achieved thereby. Also, for up to 20% bentonite blend mix, 0.7 water–cement ratio gives the optimal compressive strength.
- Bentonite is more economical as it is now cheaper than cement, hence when used as a blend; it produces more cost effective concrete.

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