

EFFECT OF CURING CONDITIONS ON CONCRETE CONTAINING BENTONITE

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Abstract

The main purpose of this study was to examine bentonite as a partial replacement for cement and to see how curing conditions affect the strength and durability of the resulting concrete. Bentonite was used at replacement levels of 5%, 10%, 15%, and 20%, while the control concrete contained no bentonite. Compressive strength, split tensile strength, and chloride migration were measured after 28 days under normal water curing and steam curing. The test results were compared to assess the effect of both bentonite content and curing method. Among the mixes, BN-5 cured with steam produced the highest compressive and split tensile strengths. The lowest chloride migration was measured for BN-20 under steam curing, showing the best resistance to chloride penetration among the mixes tested.

1. Introduction

There is an increasing demand in the reduction of the carbon dioxide generated from construction related activities due to the need to reduce greenhouse gas emissions. Concrete makes an important part of this problem as production of cement is responsible for a significant share of the emissions related to the material [1]. One way to reduce cement-related emissions is to replace some of the cement with supplementary materials with pozzolanic properties. This reduces cement consumption and takes advantage of other locally available resources. This purpose has been investigated for many natural and industrial materials. Bentonite is available in abundance in Pakistan and can be procured at a relatively low cost, thus it is a useful material to explore as partial cement replacement. It can be used in concrete to

reduce the amount of cement needed and to make concrete more sustainable to produce.

This study focuses on concrete that contains bentonite with the goal of finding a cost-effective mixture that has good durability and strength. The work also considers how the amount of bentonite and the curing method affect concrete performance. After casting, the specimens were split into two groups. One group was kept in normal water curing, whereas the other group was placed under steam curing. Proper curing is essential for concrete, as adequate moisture and an appropriate temperature are required for continued cement hydration. In this study, specimens remained in their respective curing conditions for 28 days before testing [2].

For conventional concrete, curing is generally maintained for a minimum of seven days when the

temperature remains above 5°C (40°F), or until approximately 70% of specified compressive and flexural strength has been obtained. For high-early-strength concrete cured above 10°C (50°F), the required period can be reduced to approximately three days. Steam curing is commonly adopted where rapid strength development is desirable. It exposes concrete or other cement-based materials to a warm, humid environment through the controlled supply of steam at atmospheric or elevated pressure. In atmospheric steam curing, the enclosure temperature is normally maintained within the range of 40–70°C (100–160°F). This approach is especially useful where early strength is required or where additional heat is needed to promote hydration under cold conditions.

Temperature control is important during both heating and cooling in steam curing, and the rate of temperature change should not exceed 0.6°C/min. Before cement-lined pipes enter the steam chamber, appropriate end caps should be firmly installed. After spinning, the pipes should remain capped within two hours to prevent prolonged exposure. The caps should stay in place until the pipe is connected to the field system. In addition, the cement lining must be kept moist and protected from freezing until delivery. Moisture protection should also be maintained after completion of the steam-curing process. Excessive or uncontrolled temperature variation may cause undesirable volume changes in cement lined materials. Thus curing temperatures should be controlled within the limits specified [3].

Although cement is a vital component of conventional concrete, its production is associated with large emissions of carbon dioxide. This environmental impact has encouraged the investigation of alternative cementitious materials that can partially replace cement. Bentonite is of interest because its pozzolanic characteristics permit its use at suitable replacement levels in cement-based mixtures. Accordingly, the present study incorporated different bentonite contents as partial cement replacements and evaluated the concrete under two curing regimes to determine their effects on performance.

Testing PROGRAM

Materials And Their Properties

Fauji Cement was selected as the cementitious material, and its suitability was checked in accordance with ASTM C150 [4]. The bentonite used in the mixtures was sourced from Karak, Khyber Pakhtunkhwa, Pakistan; their physical as well as chemical characteristics are presented in Table 1 and Table 2. Lawrancepur quarry sand was used as the fine aggregate, whereas crushed granite obtained from the Margalla Hills was used as the coarse aggregate. Both aggregates were subjected to sieve analysis following ASTM C-136 [5]. The obtained particle-size distributions were within the requirements of ASTM C-33 [6], confirming their suitability for the concrete mixtures. The corresponding gradation curves are presented in Figure 1. Ordinary tap water was used for both mixing and curing in accordance with ASTM C1602 [7].

Table 1: Chemical properties of OPC and Bentonite.

Chemicals	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	LOI	Total
OPC	17.4	10.2	3.6	1.8	62.3	0.9	1.4	2.4	100
BN	56.88	16.90	12.27	3.71	0.55	-	-	6.89	100

Table 2: Physical properties of OPC and Bentonite.

Name of Property	OPC	BN
Specific Gravity	3.07	2.82
Consistency of cement	29.7	25.55
Initial setting time (min)	115	-
Final setting time (min)	243	-
Soundness	No Expansion	No Expansion

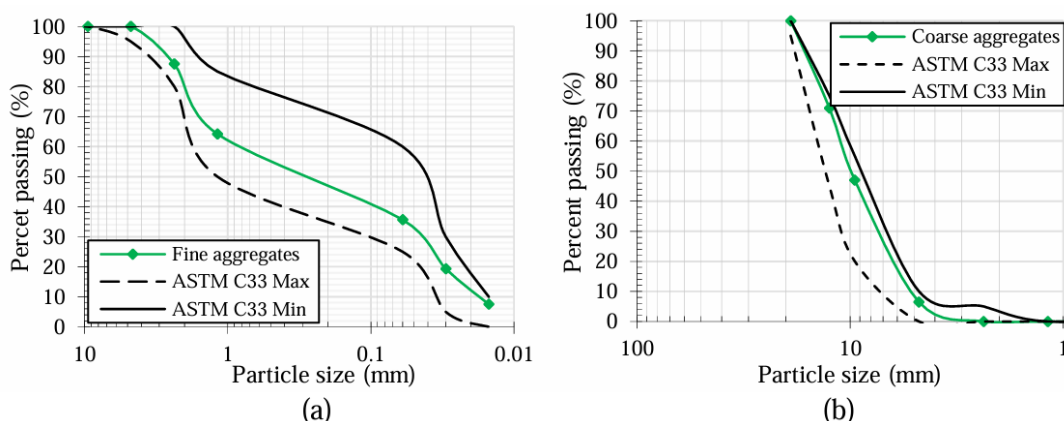


Figure 1: Granulometry of (a) fine aggregates (b) coarse aggregates

Construction and Testing of Samples

For each batch, the constituent materials were weighed according to the selected mix proportions before mixing. Concrete mixing was carried out using an electric mixer operated at a speed of 30 rpm, as shown in Figure 2(a). Individual batches were mixed separately according to the requirements of each experimental test and the number of specimens to be prepared. 03 specimens were produced from each batch, as shown in Figure 2(b), and the average of the three measured results was used to represent each test condition.

Once the specimens had been cast, they were divided into two groups according to the curing

method. The first group was placed in steam curing, as shown in Figure 2(c), while the second group was kept under normal curing conditions, as shown in Figure 2(d). After a 28-day curing period, both groups of specimens were subjected to testing. Compressive strength and split tensile strength tests were conducted to evaluate the mechanical performance of the concrete. In addition, a chloride migration test was carried out to evaluate its durability and resistance to chloride ion penetration. The mix proportions of the concrete used for the study are shown in Table 3.

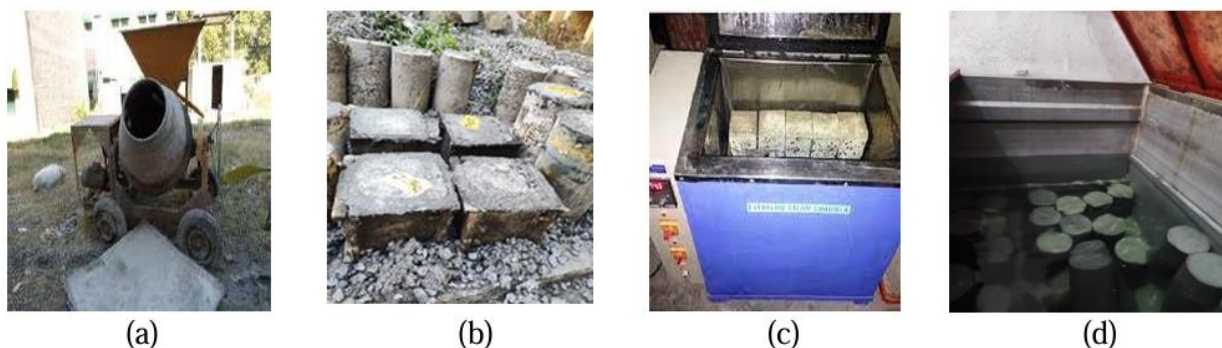


Figure 2: (a) Concrete Mixer (b) Concrete Specimens (c) Steam Curing (d) Normal Curing

Table 3: Concrete Mix Proportions

Mixes	Cement (Kg/m ³)	Bentonite (Kg/m ³)	Water (w/c=0.5) (Kg/m ³)	Fine Aggregate (Kg/m ³)	Coarse Aggregate (Kg/m ³)
Control	320	0	160	640	1280
BN-5	304	16	160	640	1280
BN-10	288	32	160	640	1280
BN-15	272	48	160	640	1280
BN-20	256	64	160	640	1280

Results and discussion

Compressive Strength Test

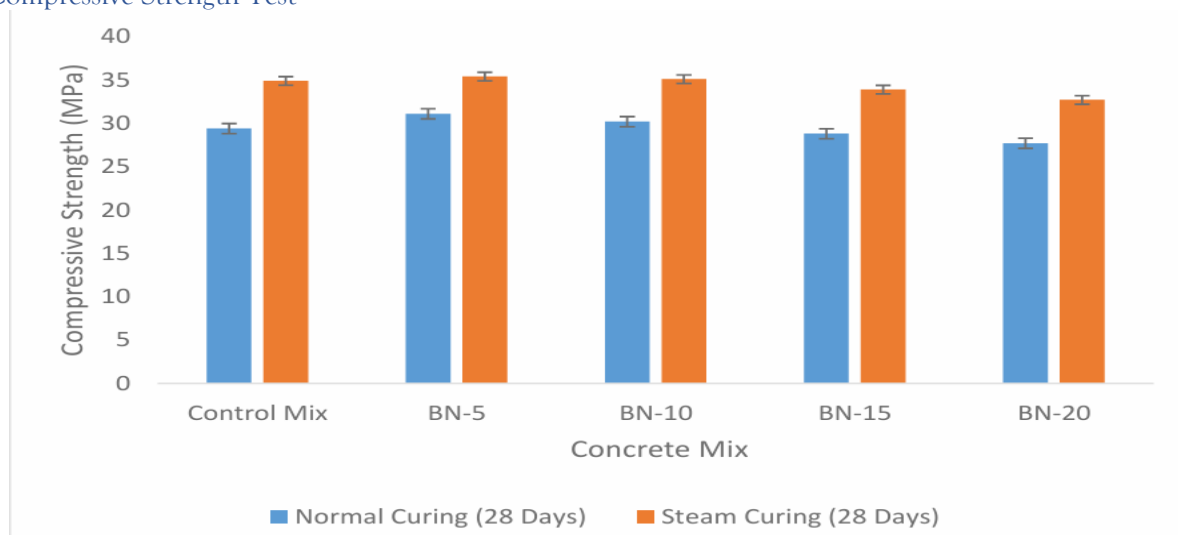


Figure 3: Compressive Strength of Different Concrete Mixes

Compressive strength of the specimens in the form of a cylinder was determined according to ASTM C39 [8]. Figure 3 shows the compressive strengths of the control mix and the bentonite mixtures cured normally and by steam for 28 days. For each mixture, steam curing yielded higher compressive strengths than normal curing. Steam, compared to normal curing, improved the compressive strength of each mixture. Whereas the control

concrete gained 18%, the increase was 13% for BN-5 and 15% for BN-10. BN-15 gained 17%, and BN-20 increased by 18%. Therefore, replacing cement with bentonite improved the compressive strength of steam-cured concretes; however, the increase varied depending on the bentonite content.

Split Tensile Strength Test

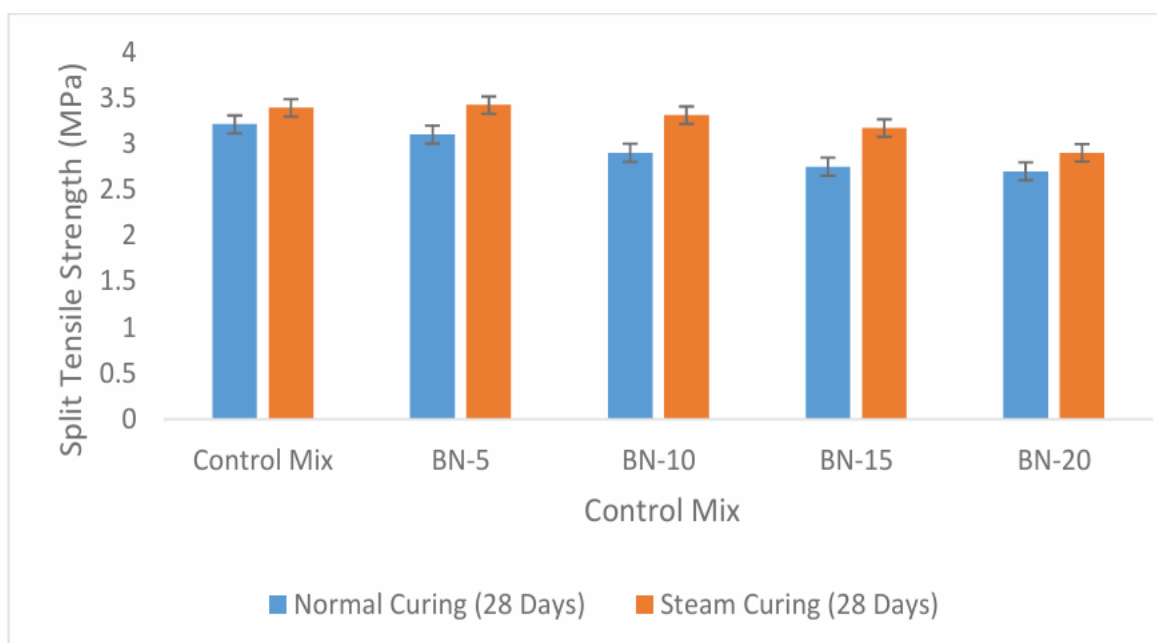


Figure 4: Split Tensile Strength of Different Concrete Mixes

Split tensile strength test was carried out following ASTM C496 [9]. Figure 4 shows the obtained values for the control and bentonite mixtures after normal and steam curing. For all the considered mixtures, the specimens under steam curing exhibit higher split tensile strengths compared to normally cured ones.

The control mixture recorded a 4% increase in split tensile strength when using steam curing. The increase was 11% for BN-5, 11.4% for BN-10,

14.9% for BN-15, and 12% for BN-20. Thus, it can be seen that among the mixtures, BN-15 demonstrated the highest improvement in split tensile strength between the two curing conditions.

Chloride Migration Test

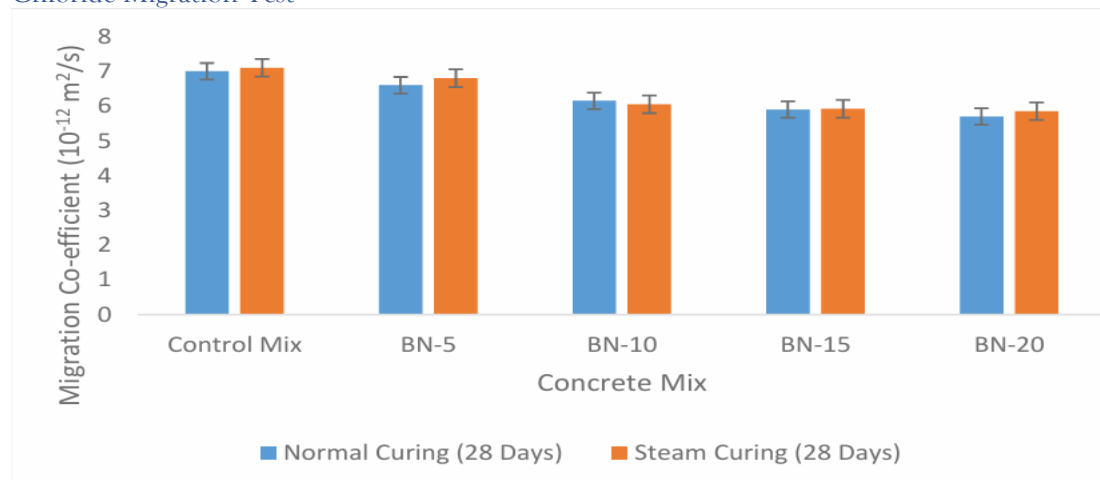


Figure 5: Chloride Migration Results of Different Concrete Mixes

The chloride migration coefficient was determined using ASTM C1202. Figure 5 shows a comparison between the control concrete and the mixtures with 5%, 10%, 15% and 20% bentonite under steam curing. It can be seen that there was a gradual decline of the coefficient at an increase in bentonite content. As compared to the control blend, it is reduced by 4.7% for BN-5, 10% for BN-10, 15% for BN-15, and 20% for BN-20. This tendency suggests that an increase in bentonite replacement decreases chloride-ion transport through the concrete under steam curing.

A similar comparison was made for the normally cured specimens. Bentonite also decreased the chloride migration coefficient under normal curing, with reductions of 4.7% for BN-5, 11% for BN-10, and 14.9% for BN-15. The BN-20 mixture had the largest decrease, amounting to 22%. Therefore, bentonite improved the resistance to chloride-ion transport under both curing regimes. The BN-20 mixture exhibited the greatest reduction in chloride migration and thus, provided the highest resistance to chloride penetration.

Conclusions

Steam curing achieved higher compressive strength than normal curing method for all the BN concrete mixtures. The difference was not the same for all the mixture proportions but the steam-cured specimens were overall stronger.

Among the mixes that went through steam curing, BN-5 presented the highest split tensile strength. The results suggest that replacing 5% of the cement by bentonite provided higher tensile properties than the other replacement ratios studied in this work.

The introduction of bentonite into the mix reduced chloride migration and the highest reduction was achieved with bn-20. Steam curing was linked to a higher reduction than normal curing method. Within the range of mixtures studied, BN-20 subjected to steam curing provided the strongest resistance to chloride penetration.

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