World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:11, No:1, 2017

Waterproofing Agent in Concrete for Tensile Improvement

Muhamad Azani Yahya, Umi Nadiah Nor Ali, Mohammed Alias Yusof, Norazman Mohamad Nor, Vikneswaran Munikanan

Abstract**—**In construction, concrete is one of the materials that can commonly be used as for structural elements. Concrete consists of cement, sand, aggregate and water. Concrete can be added with admixture in the wet condition to suit the design purpose such as to prolong the setting time to improve workability. For strength improvement, concrete is being added with other hybrid materials to increase strength; this is because the tensile strength of concrete is very low in comparison to the compressive strength. This paper shows the usage of a waterproofing agent in concrete to enhance the tensile strength. High tensile concrete is expensive because the concrete mix needs fiber and also high cement content to be incorporated in the mix. High tensile concrete being used for structures that are being imposed by high impact dynamic load such as blast loading that hit the structure. High tensile concrete can be defined as a concrete mix design that achieved 30%-40% tensile strength compared to its compression strength. This research evaluates the usage of a waterproofing agent in a concrete mix as an element of reinforcement to enhance the tensile strength. According to the compression and tensile test, it shows that the concrete mix with a waterproofing agent enhanced the mechanical properties of the concrete. It is also show that the composite concrete with waterproofing is a high tensile concrete; this is because of the tensile is between 30% and 40% of the compression strength. This mix is economical because it can produce high tensile concrete with low cost.

Keywords**—**High tensile concrete, waterproofing agent, concrete, rheology.

I. Introduction

CONCRETE structures are being used widely to construct buildings, bridges and other infrastructure elements. The contemporary interest of safety, including for defense strategies, leads to a demand for producing high tensile concrete. Tensile strength is one of the important properties of concrete [1]. This is because concrete structures are exposed to highly vulnerable to tensile cracking when being imposed by impact loading. This is due to the various kinds of effects and applied loading itself, and nowadays having the situation of highly dynamic scenarios such as explosion and terrorist attacks. The interest has expanded from civil defense dwellings and pure military targets to civil structures used for different civil functions. The main criteria of the dynamic impact structure are that the structure must have a high tensile factor to prevent concrete spalling [1]. Previous research indicates that spalling occurs when and where the tensile strength of the strain-softening materials is reached. This research focus on the composite concrete mix with a waterproofing agent to increase the tensile strength of the mix that is appropriate for dynamic loading. Normally, waterproofing is used as a coating and layering to a building structure, and is used to prevent water seepage from damaging the structure. Waterproofing membranes and waterproof coatings have been used and selected by a majority of construction companies as their water resistant solutions. Based on previous research, adding steel fiber into a concrete mix is too expensive as a solution for concrete strength improvement. To counter this, an experiment was conducted by adding waterproofing agent to the concrete mix. Several brands of waterproofing agent were used in this research. In this study, three common types of waterproofing agent were used to enhance the tensile strength improvement of the concrete.

Muhamad Azani Yahya, Umi Nadiah Nor Ali, Mohammed Alias Yusof, Norazman Mohamad Nor and Vikneswaran Munikanan are with the National Defence University of Malaysia, 57000 Kuala Lumpur, Malaysia (phone: +60390513400; fax: +60390513472; e-mail: azani@upnm.edu.my).

II. Objectives

The objectives of this research are:

i. To evaluate the mechanical properties of composite concrete with waterproofing agent; and,
ii. To identify the characteristic of the waterproofing agent in the concrete mix towards producing high tensile concrete.

III. Methodology

The concrete mix design used in this research was grade 30MPa. This research identifies the suitable waterproofing agent to increase the concrete strength. The objectives and definition of the waterproofing agent have been discussed in the literature review. The comparison of the three brands of waterproofing agent was conducted by laboratory testing. The method of selecting the best waterproofing agent was reviewed in the literature review section which provides preliminary knowledge about the material of the waterproofing agent. In this research, there are two methods that helped in the accomplishment of the objectives, namely:

A. Actual Concrete Production

Three shapes of the specimen need to be made which consist of a cube, cylinder and beam. Each type of specimen should contain a different waterproofing agent. Three specimens of each shape must be made to get the minimum average of the experimental analysis. The total number of specimens to be made is 36, including the control specimens.

B. Laboratory Testing and Experimental Analysis

Three types of testing should be carried out on the specimens. The tests are compression test, flexural test and splitting tensile test. The compression test will be conducted on a cube specimen with an average of three cubes. The flexural test is for the beam specimen and the splitting tensile test is for the cylinder specimen. Each type of specimen must be tested with an average of three specimens.

Concrete mix grade 30 (G30) was used, and mixed together with cement, aggregate, water, sand and admixture in the concrete mix procedure. Concrete grade 30 indicates that the strength of concrete at 28 days will become 30 N/mm^2. If the concrete strength did not achieve the targeted strength, the concrete mix will be considered as failed. In this case, the next procedure in the study cannot be continued and must repeat the concrete mix design again.

The slump test was done after the concrete was batched during the laboratory mix session. The function of the slump test is to measure the workability of the concrete mix. The workability term in this context is the behavior of fresh concrete in handling, delivery and placing. The workmanship was simplified during construction work, thus it can shorten construction time.

The control specimen is the concrete mix without any addition of admixture or additive that can change the original strength. The concrete mix ingredients consist of water, fine aggregate, coarse aggregate and cement (OPC). These raw materials are combined and mixed together based on a calculation of concrete mix design form. The concrete mix design form is divided into five stages in completing the final calculation. The concrete mix design is shown in Fig. 1.

Stage	Item	Reference of calculation	Values
1	1.1 Characteristic Strength	Specified	30 N/mm2 at 28 days; Propotion defective 5 %
	1.2 Standard deviation	Fig. A3	- N/mm2 or no data 8 N/mm2
	1.3 Margin	C1 or specified	(K = 1.64) 1.64 x 8 = 13.12 N/mm2
	1.4 Target mean strength	C2	30 + 13.12 = 43.12 N/mm2
	1.5 Cement Type	Specified	OPC
	1.6 Aggregate type : Coarse		Crushed / ~~uncrushed~~
	Aggregate type : Fine		~~Crushed~~ / uncrushed
	1.7 Free-water / cement ratio	Table A.4	0.53 } Use the lower value 0.53
	1.8 Maximum free-water/cement ratio	Specified	0.65
2	2.1 Slump or vebe time	Specified	Slump = 30 - 60 mm or Vebe time 3 - 6 s
	2.2 Maximum Aggregate size	Specified	20 mm
	2.3 Free- water content	Table A.5	2/3 (180)+ 1/3 (210) kg/m3
3	3.1 Cement Content	C3	190/0.53 = 358 kg/m3
	3.2 Max. Cement Content	Specified	.... kg/m3
	3.3 Min. Cement Content	Specified	275 kg/m3
			use 3.1 if < 3.2
			use 3.3 if > 3.1 358 kg/m3
	3.4 Modified free- water cement ratio		....
4	4.1 Relative density of agg. (SSD)		2.7 — known / ~~assumed~~
	4.2 Concrete density	Fig. A5	2430 kg/m3
	4.3 Total aggregate content	C4	2430 - 358 - 190 = 1882 kg/m3
5	5.1 Grading of fine aggregate	% passing 600 µm sieve	38%
	5.2 Proportion of fine agg	Fig. A6	38%
	5.3 Fine aggregate content	} C5	1882 x 0.38 = 715.6 kg/m3
	5.4 Coarse aggregate content		

Quantities	Cement	Water	Fine agg	Coarse agg (kg)			
Per m3 (to nearest 5 kg)	358	190	715.16	389	778	38.9	0
Per trial mix of 0.05 m3	17.9	9.5	35.76	19.45	38.9	38.9	0

Complete concrete mix design form

Fig. 1 Concrete design mix for 30 MPa

IV. Literature Review

Concrete structures are normally being impacted by static and dynamic loads based on the time duration of an action. Dynamic loads span over a range of time intervals [2]. The different time frames yield to the different types of responses towards the materials itself and the response of the whole structure, and thus, create different demands for the analytical routines and material representation. Dynamic moving creates the response of the structure. During the time frame, the deformation of the structure changes and thus, the internal and external forces for the structure change. If a moving object hits a structure, the response will depend on both the velocity and properties [3].

Dynamic impact behavior is exposed to blast loading propagation through the atmosphere and high pressure impulsive loading over short durations [4]. The response of concrete under tensile loading is crucial for its usage and application because concrete is much weaker in tension than in compression. Understanding the response of concrete on tensile conditions is the key for understanding and using concrete in structural applications. Table I shows the correlation between normal concrete and high tensile concrete in compression and tensile.

TABLE I
Defining High Tensile Concrete [5]

Types of Concrete	Compression Value (MPa)	Tensile Value (MPa)
Normal Concrete	According to Design Mix	10% of Compression Value
High Tensile Concrete	According to Design Mix	30% - 40% of Compression Value

In the construction process flow, the use of a waterproofing agent is to prevent water seepage through the structure [6]. It is normally used on dry concrete as a layer for waterproofing. No previous literature shows the usage of waterproofing to enhance the tensile strength of concrete. This research elaborates the use of waterproofing in concrete to increase the tensile strength.

Previous research shows that there are many initiatives being done to enhance the flexural strength of the hardened concrete. This phenomenon occurs because the use of steel reinforcement is expensive and concrete has a behavior of stresses. Innovation in enhancing tensile strength has been done by including the composite of concrete with:

- Fly ash;
- Glass fiber;
- Polypropylene fiber;
- Polymer fiber;
- Synthetic fiber; and
- Steel fiber.

V. Result

The basic strength of the concrete is being measured by compression test. The mechanical properties of the samples are being tested using compression test and tensile test. Samples are being mixed with three (3) brands of liquid waterproofing that are normally used in Malaysian construction practice. For the compression test, concrete cubes with the dimensions of 150mm x 150mm x 150mm were used and the results shown in Table II.

TABLE II
Result of Compression Test

Type of mixing agent	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
Normal Concrete	25.68	24.8
	23.55	
	25.11	
Concrete + 5% mixing agent BRAND A	35.46	35.0
	33.20	
	36.36	
Concrete + 5% mixing agent BRAND B	25.70	23.8
	21.90	
	N/A	
Concrete + 5% mixing agent BRAND C	32.70	35.7
	37.20	
	37.20	

The tensile test is crucial because this test will determine on the success of this research. The results for the tensile testing are shown in Table III.

TABLE III
Result of Tensile Test

Type of mixing agent	Tensile Strength (N/mm^2)	Mean Tensile Strength (N/mm^2)
Normal Concrete	1. 2.560	2.60
	2. 3.100	
	3. 2.090	
Concrete + 5% mixing agent TYPE A	1. 9.770	11.10
	2. 10.89	
	3. 12.30	
Concrete + 5% mixing agent TYPE B	1. 10.30	9.70
	2. 10.60	
	3. 8.300	
Concrete + 5% mixing agent TYPE C	1. 12.10	12.10
	2. 12.10	
	3. 12.10	

The mechanical properties of composite mix concrete with a waterproofing agent were determined, and it is clearly shown that the waterproofing agent enhanced the mechanical properties of the concrete. This is because the waterproofing agent acts as synthetic fibers that bond the ingredient of concrete. The rheology of waterproofing in concrete is shown in Fig. 2.

From the analysis, it is shown that concrete with waterproofing can act as a high tensile concrete because it give higher value of tensile, which are in the range of a 30% - 40% from the compression value. The results proof that it is similar to Table I because of the percentage tensile value in the range of 30%-40% and the mix considered as high tensile concrete.

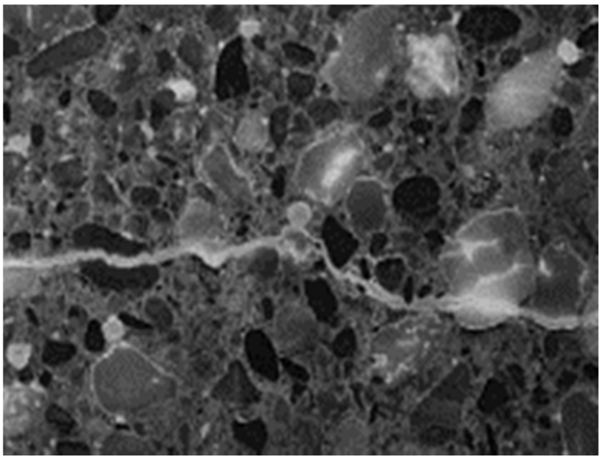

Fig. 2 Rheology of composite concrete with waterproofing agent

VI. Conclusion

As is known, most of a building structure is made from concrete, which is an artificial material that contains cement, water, coarse aggregate, fine aggregate and admixture. The aim of this study was to evaluate the strength improvement of concrete by adding a waterproofing agent, and to evaluate the resulting concrete strength when mixed with a waterproofing agent. The conventional method of using a waterproofing agent in construction is to ensure that structural elements are waterproof and can retain water. No moisture absorption or seepage allows for the structure due to the design and construction method. The results show that the use of a waterproofing agent in concrete acts as a synthetic fiber that contributes to a marked increase in tensile strength. This method can be used for producing high tensile concrete at low cost. This contributes to the innovation, not just for method and technology, but also in construction economics in terms of producing standard concrete with high tensile performance. This research also explores the different use of waterproofing agents such as construction materials. High tensile concrete suitable for extremely durable structures such as bunkers and structures subjected to blast loading which need an increased level of the structural integrity.

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