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Development of mathematical model to predict the variation of split tensile strength of self-compacting concrete

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Abstract

The study developed a predictive model to monitor the behaviour of split tensile strength on self-compacting concrete, several experts has applied experimental data to generate split tensile strength of concrete in general, but the study determine to developed mathematical model using analytical derived solution to monitor split tensile strength modified with other addictive's for self-compacting concrete, such non-homogeneous system were developed to monitor the behaviour of split tensile strength of self-compacting concrete, it is observed that split measure the brittle of the materials thus characterized the tensile strength of concrete, the analysis of the split tensile were monitored on the variation of curing age, fluctuation on the interval of seven days were observed, the predictive values compared with experimental result generated closed fits, similar results were experienced from the numerical simulation values that split were monitored at every twenty four hours, the predictive and experimental values also maintain a close fits, these implies that the development of non-homogeneous derived solution has developed a predictive model that has monitored the system at interval of seven days and every twenty fours. Experts can apply this concept to monitor the behaviour of split tensile strength in any grade of concrete design.

Keywords: Mathematical model, Split Tensile, strength and self-compacting concrete.

1. Introduction

Elinwa & Mamuda (2014) carried out an investigation to find out the fluidity of Portland cement paste and its compatibility with sawdust ash (SDA) as powder material for self-compacting concrete blends. Consequences of the examination demonstrated that saturation was accomplished at water content proportions of 0.40 and 0.420, at measurements of naphthalene sulfonate super plasticizers of 3.50% and 2.0%, separately. Mahmoud et al (2013) studied the likelihood of creating fiber reused self-compacting concrete (FRSCC) utilizing decimations as coarse aggregate (crushed red brick and crushed ceramic). Polypropylene strands were utilized as a part of reused self-compacting concrete (RSCC) to enhance the fresh and hardened properties of this sort of concrete.

Oladipupo et al (2015) compared the rheological properties and compressive strengths of self-compacting concrete and traditional cement concrete. They observed that the early age compressive strength was low when compared to conventional concrete and this was basically as a result of the inclusion of the super plasticizers. Ofuyatan et al (2015) carried out a study on the durability properties of Self Compacting Concrete with partial replacement of Palm Oil Fuel Ash (POFA). Ede & Adegbite (2013) also studied the characteristics of self-compacting concrete at different replacement levels of cement with limestone powder. Ferraris et al (2000) carried out studies to experiment flow characteristics of self-compacting concrete utilizing various devices: two concrete rheometers and several standard tests. They discovered that the plastic viscosities measured with the two rheometers were correlated at 84%, and that a self-compacting mixture is not defined by its high slump and slump spread alone.

Akram et al (2008) [1] varied the proportion of bagasse ash, dosage of super plasticizer for flowability and water/binder ratio and kept the proportion of cement and water content constant in trying to design a low cost self-compacting concrete

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mix. Their experimental results substantiated the possibility of developing low cost self-compacting concrete with the use of bagasse ash. (Bouzoubaa & Lachemi (2001) [3],67 studied the concrete made with high volumes of fly ash. From their results it could be seenthat high volumes of Class F fly ash can be utilized the production of self-compacting concrete. Patil et al (2015) carried out experimental studies on the strength and durability properties of high performance self-compacting concrete (HPSCC) made with manufactured sand and as partial replacement of cement by mineral admixture (Metakaolin). The rheology properties was determined by tests as filling, passing ability and segregation resistance including pH and Temperature. Strength properties were determined by Compressive, split tensile tests. Flexural strength and Young's Modulus were examined and durability properties were determined by Rapid Chloride Penetration Test (RCPT) Nunes et al (2006) [5], proposed a state of the art method to quantify self-compacting concrete mixture robustness. They noted the need for an enhanced self-compacting concrete mix proportion for introducing this new technology to the concrete industry successfully.

Rao et al (2013) studied the effect of H_2SO_4 and HCl on High strength self-compacting concrete. They observed a remarkable concrete strength reduction on addition of these acids. Strength of concrete is commonly considered as its most valuable property. The strength of concrete is defined as the maximum stress a standard specimen can carry under load (Abrams, 1971; Gupta & Gupta, 2004; Neville & Brooks, 1996; Popovics, 1998) [4, 6, 7]. There are several standard ways to characterize the strength of concrete Bapat et al (2004) [2] carried out a number of extensive mix design trials to arrive at a suitable mix-proportion for N-30 grade using 20mm maximum size aggregates. Strength

2. Theoretical Background

$$\frac{d^2{}_{cu}}{dz^2} = \left(\frac{w}{c} + \frac{c}{pk} + \frac{c_{sg}}{s} + \frac{sp}{w}\right)\frac{d_{cu}}{dz} \qquad (1)$$

production and evaluation of self-compacting concrete self-compacting

$$\frac{d^2{}_{cu}}{dz^2} + \left(\frac{w}{c} + \frac{c}{pfa} + \frac{c_{sg}}{sand} + \frac{sp}{w}\right)\frac{d_{cu}}{dz} + \left(K + \phi + V\right) f_{cu} = 0 \qquad (2)$$

Let $\alpha = \frac{w}{c} + \frac{c}{pfa} + \frac{c_{sg}}{sand} + \frac{sp}{w}$ and $\beta = \gamma + \phi$

$$\frac{d^2 f_{cu}}{dz^2} + \alpha \frac{df_{cu}}{dz} + \beta f_{cu} = 0 \qquad (3)$$

Auxiliary equation becomes

$$m = \frac{-\alpha \pm \sqrt{\alpha^2 - 4\beta}}{2}$$

Hence, $f_{cu}(z) = ae^{\left(\frac{-\alpha + \sqrt{\alpha^2 - 4\beta}}{2}\right)z} + be^{\left(\frac{-\alpha - \sqrt{\alpha^2 - 4\beta}}{2}\right)\beta}$

(4)

If $a = b$;

Then ${}_{Cu}(z) = 2aCos\left(\frac{-\alpha + \sqrt{\alpha^2 - 4\beta}}{2}\right)z$ (5)

3. Materials and Method

3.1. Flexural and Tensile strength

Concrete has relatively high compressive strength in the range of 10 to 50 Nmm^2 and 60 to 120 Nmm^2 for high strength concrete. Tensile strength significantly low constitutes about 10% of the compressive strength (Neville & Brooks, 1996; Popovics, 1998) [4, 6].

Flexural test is done to find out the tensile strength of concrete. A typical set up recommended by British Standard is illustrated in Fig.1.

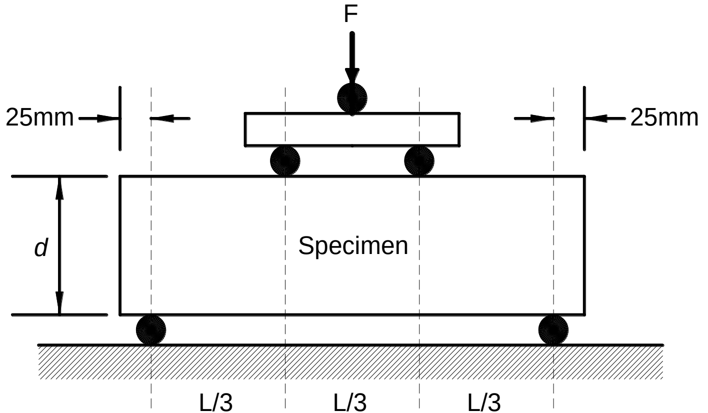

Figure 1: Flexural Beam Test Set-up

From Mechanics of Materials and analysis of Fig.1, maximum tensile stress is expected to occur at the bottom of the constant moment region within which pure bending occurs. The modulus of rapture can be calculated as:

$$f_{tb} = \frac{FL}{bd^2} \tag{6}$$

Where L= Span of specimen beam
F = Maximum applied loads
B = Breadth of beam
D = Depth of beam

Other method used in determining the tensile strength of concrete is the indirect tension test (split cylinder test or Brazilian test, Fig.2) BS 1881: Part 117:1983 and ASTM C496-71. As recommended in these standards, the splitting test is done by applying compression loads at a loading rate 0.0112 to 0.0231 MPa/s along two axial lines that are diametrically opposite on a specimen 150 x 300 mm cylinder.

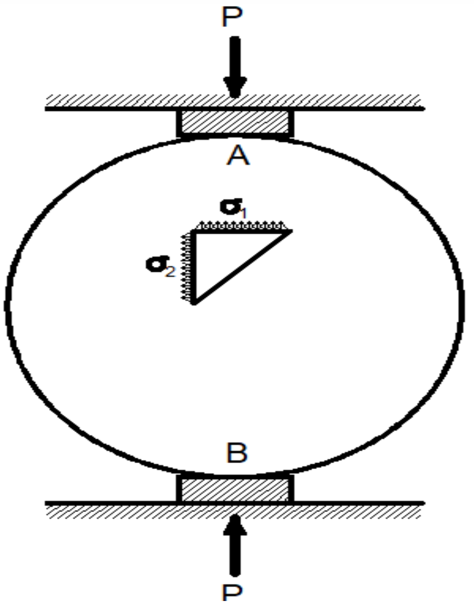

Figure 2: Tensile splitting Analysis

The splitting tensile strength is calculated using the stated formula

$$F_{st} = \frac{2P}{\pi LD} \tag{7}$$

Where L = Length of Cylinder

P =Maximum applied loads
D =Diameter of Cylinder

3.2 Requirements For Self-Compacting Concrete

3.2.1 Application Area

Self-compacting concrete can be used on pre-cast concrete placed on site. Casting of concrete structures with high quality are now being made possible by the utilization of self-compacting concrete.

3.2.2 Requirements

The workability of self-compacting concrete exceeds the highest class of consistence described in EN 206 and can be characterized by the following properties:
- Filling ability
- Passing ability
- Segregation resistance

A concrete mix can be called a self-compacting concrete if the prerequisites for each of the three qualities are satisfied.

3.2.3 Test Methods

No single method has been discovered which portrays all the pertinent workability viewpoints so every mix design ought to be tried by more than one test technique for the distinctive workability parameters. Different test methods for the different parameters are given in Table 1 and Table 2 below according to (EFNARC, 2005).

Table 1: List of Test Methods for Workability Properties of Self-Compacting Concrete (SCC)

S.N	Method	Property
1	Slump-flow by Abrams cone	Filling ability
2	T_{50cm} slump flow	Filling
3	J-ring	Passing ability
4	V-funnel	Filling
5	V-funnel at $T_{5minutes}$	Segregation resistance
6	L-box	Passing
7	U-box	Passing

Table 2: Workability Properties of SCC and Alternative Test Methods

Property		Test methods	
	Lab (mix design)	Field (QC)	Modification of test according to max aggregate size
Filling ability	Slump flow T_{50cm} slump flow V-funnel	Slump flow T_{50cm} slump flow V-funnel	none max 20mm
Passing ability	L-box U-box; Fill-box	J-ring	Different openings in L-box, U-box and J-ring
Segregation resistance	GTM test V-funnel at $T_{5minutes}$	GTM test V-funnel at $T_{5minutes}$	None

4. Results and Discussion

Predictive from Derive model Simulation and Experimental values of Split Tensile Strength are in Graphical Presentation as shown in Tables 3-8.

Table 3: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Split Tensile Strength	Experimental Split Tensile Strength
7	2.19	1.97
14	2.39	2.19
21	3.19	3.05
28	4.01	3.34

Table 4: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Split Tensile Strength	Experimental Split Tensile Strength
7	2.19	2.98
14	4.39	4.86
21	4.31	4.16
28	4.35	4.61

Table 5: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Split Tensile Strength	Experimental Split Tensile Strength
7	2.2971	2.1403
14	2.7528	2.9096
21	3.5221	3.6789
28	4.605	4.4482

Table 6: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Split Tensile Strength	Experimental Split Tensile Strength
7	2.0184	2.1801
14	2.7709	2.6092
21	3.2	3.0383
28	3.3057	3.4674

Table 7: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Compressive Strength	Experimental Compressive Strength
7	2.19	2.2003
8	2.29	2.2396
9	2.27	2.2789
10	2.319	2.3182
11	2.35	2.3575
12	2.39	2.3968
13	2.43	2.4361
14	2.47	2.4754
15	2.51	2.5147
16	2.55	2.554
17	2.59	2.5933
18	2.63	2.6326
19	2.68	2.6719
20	2.71	2.7112
21	2.75	2.7505
22	2.79	2.7898
23	2.83	2.8291
24	2.87	2.8684
25	2.91	2.9077
26	2.95	2.947
27	2.99	2.9863
28	3.034	3.0256

Table 8: Predictive and Experimental of Split Tensile Strength at Different Curing Age

Curing Age	Predictive Compressive Strength	Experimental Compressive Strength
7	2.23233	2.2181
8	2.25998	2.2563
9	2.28877	2.2945
10	2.33577	2.3327
11	2.36377	2.3709
12	2.41198	2.4091
13	2.44133	2.4473
14	2.47882	2.4855
15	2.52745	2.5237
16	2.55622	2.5619
17	2.59513	2.6001
18	2.64418	2.6383
19	2.67537	2.6765
20	2.72276	2.7147
21	2.75227	2.7529
22	2.79278	2.7911
23	2.83153	2.8293
24	2.87142	2.8675
25	2.91145	2.9057
26	2.95262	2.9439
27	2.96193	2.9821
28	3.03238	3.0203

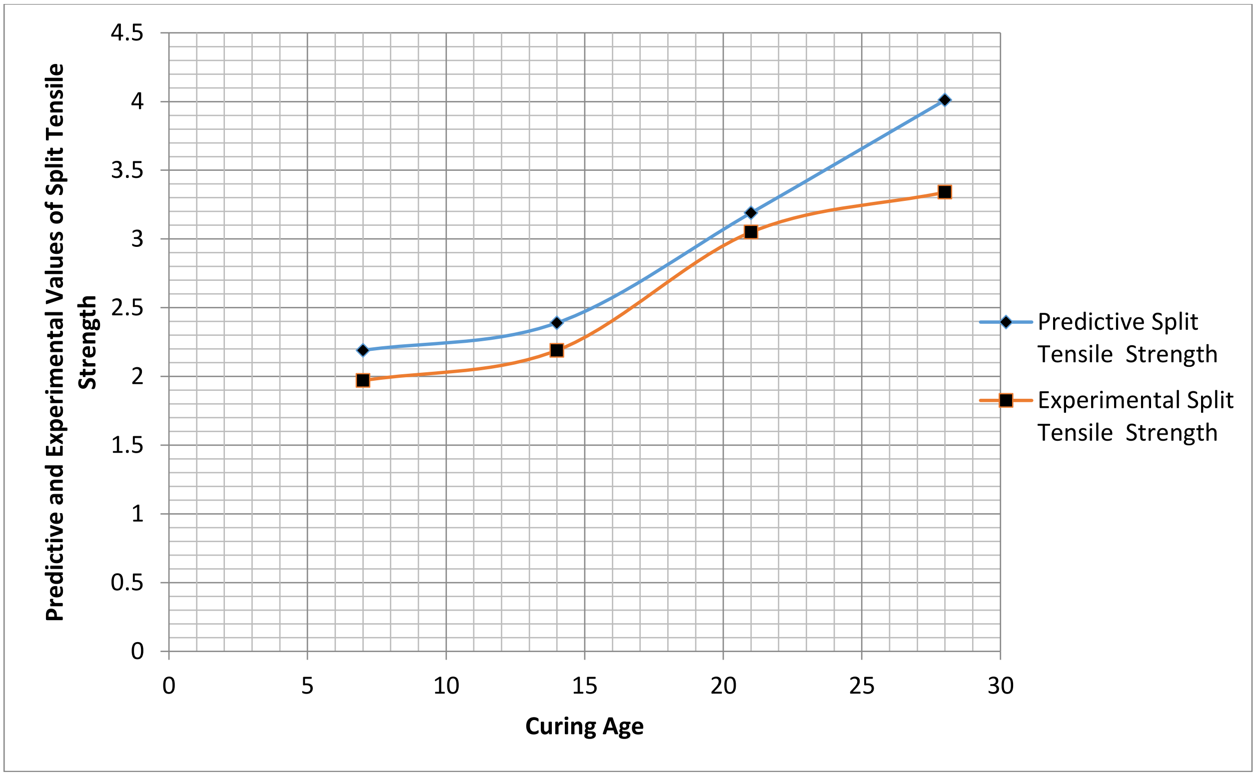

Figure 3: Predictive and Experimental of Split Tensile Strength at Different Curing Age

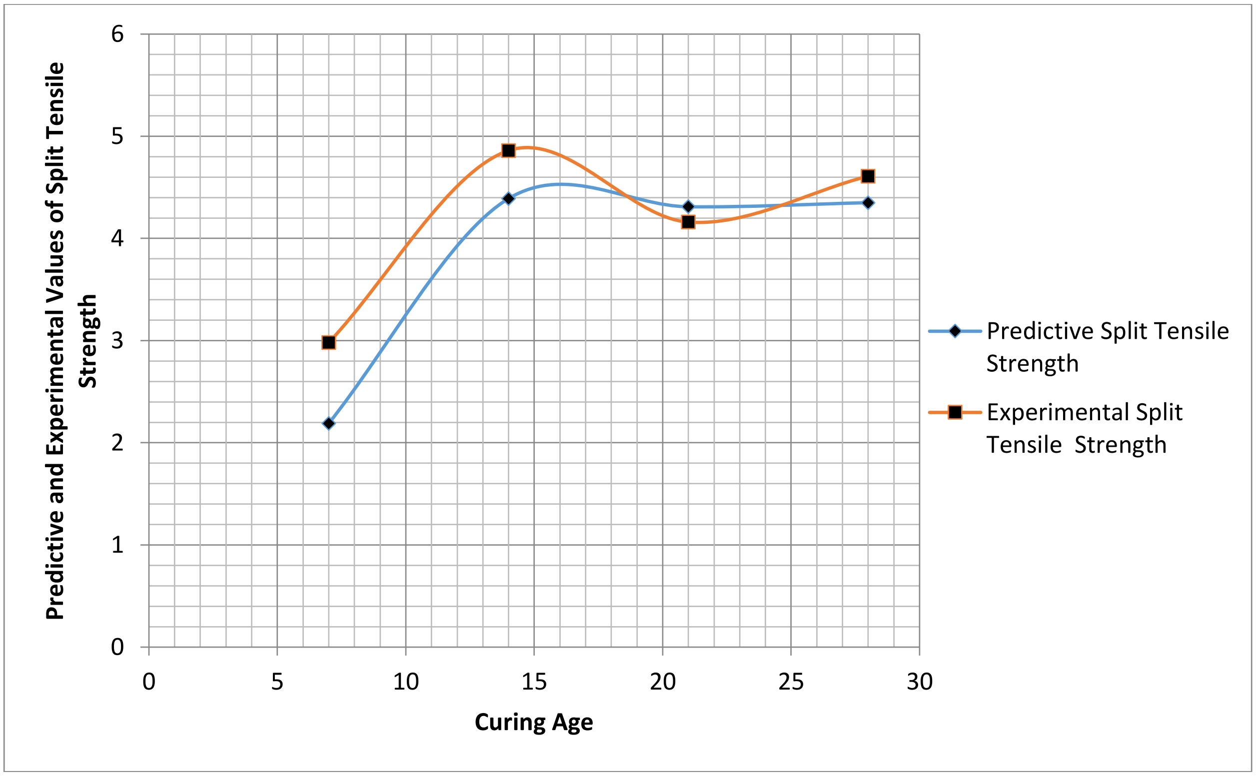

Figure 4: Predictive and Experimental of Split Tensile Strength at Different Curing Age

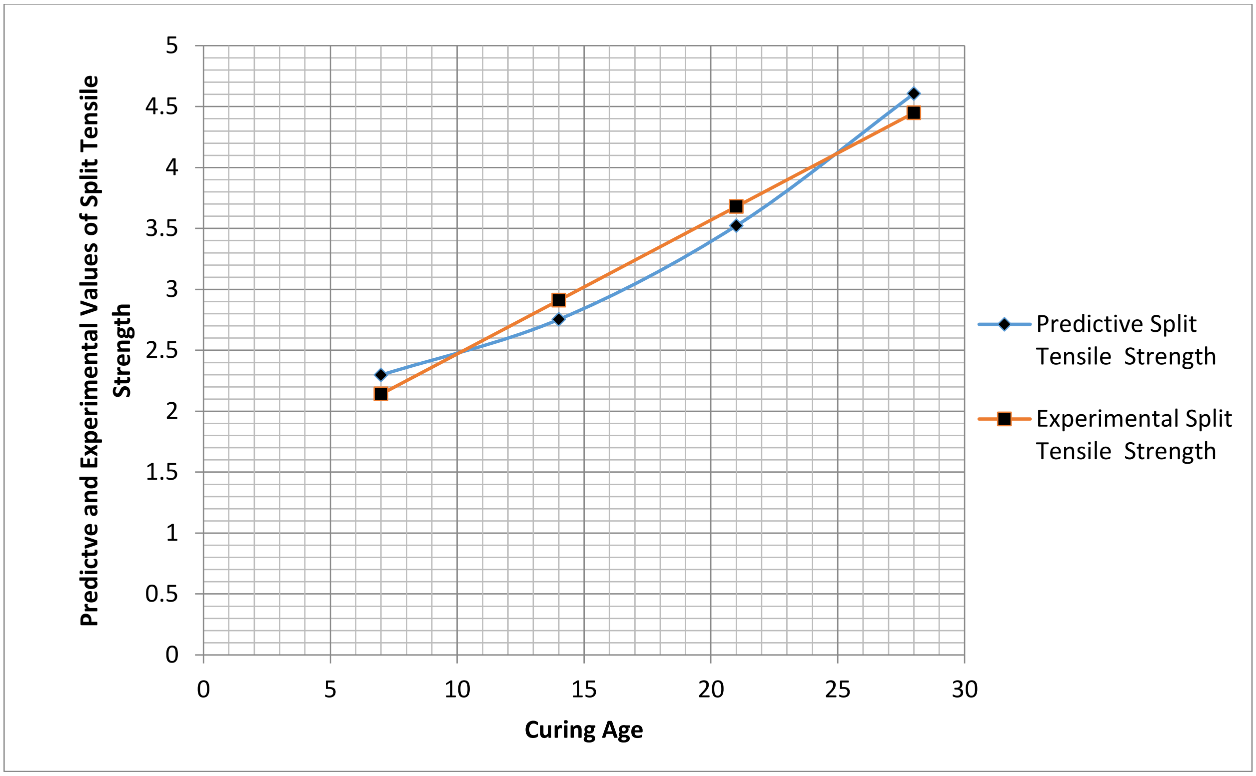

Figure 5: Predictive and Experimental of Split Tensile Strength at Different Curing Age

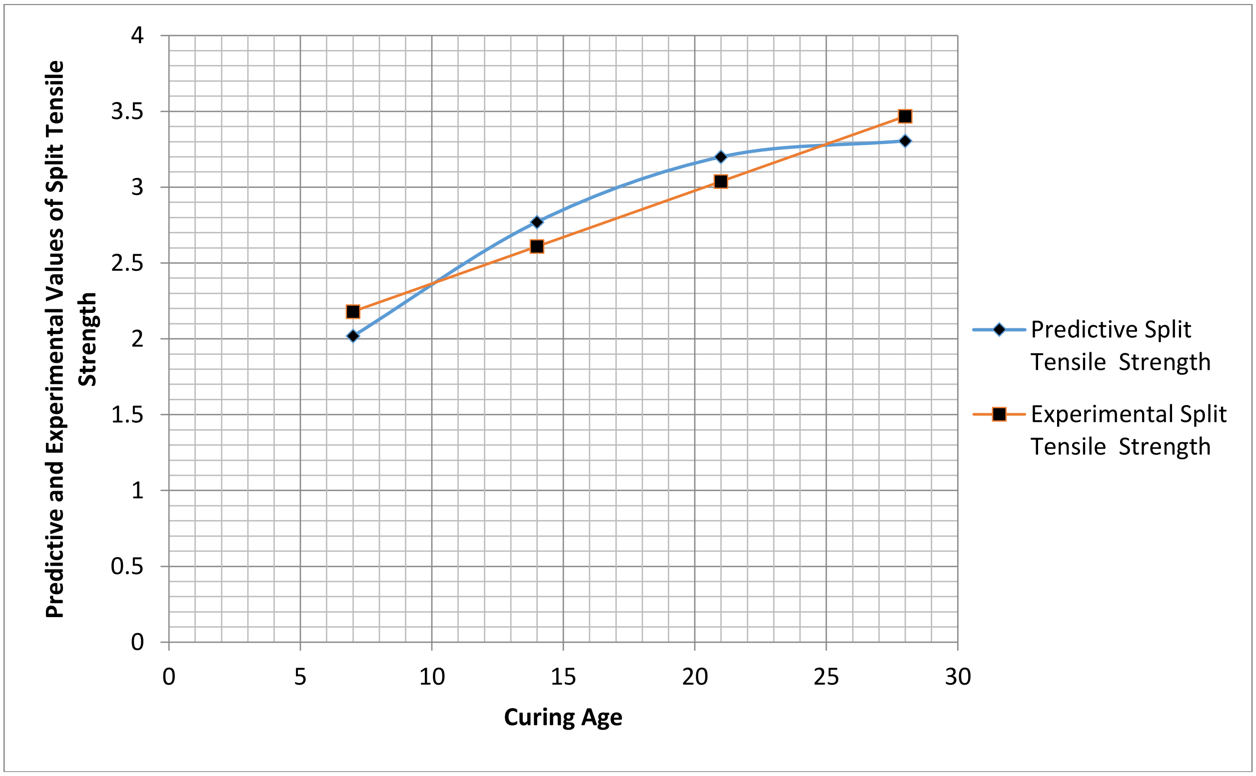

Figure 6: Predictive and Experimental of Split Tensile Strength at Different Curing Age

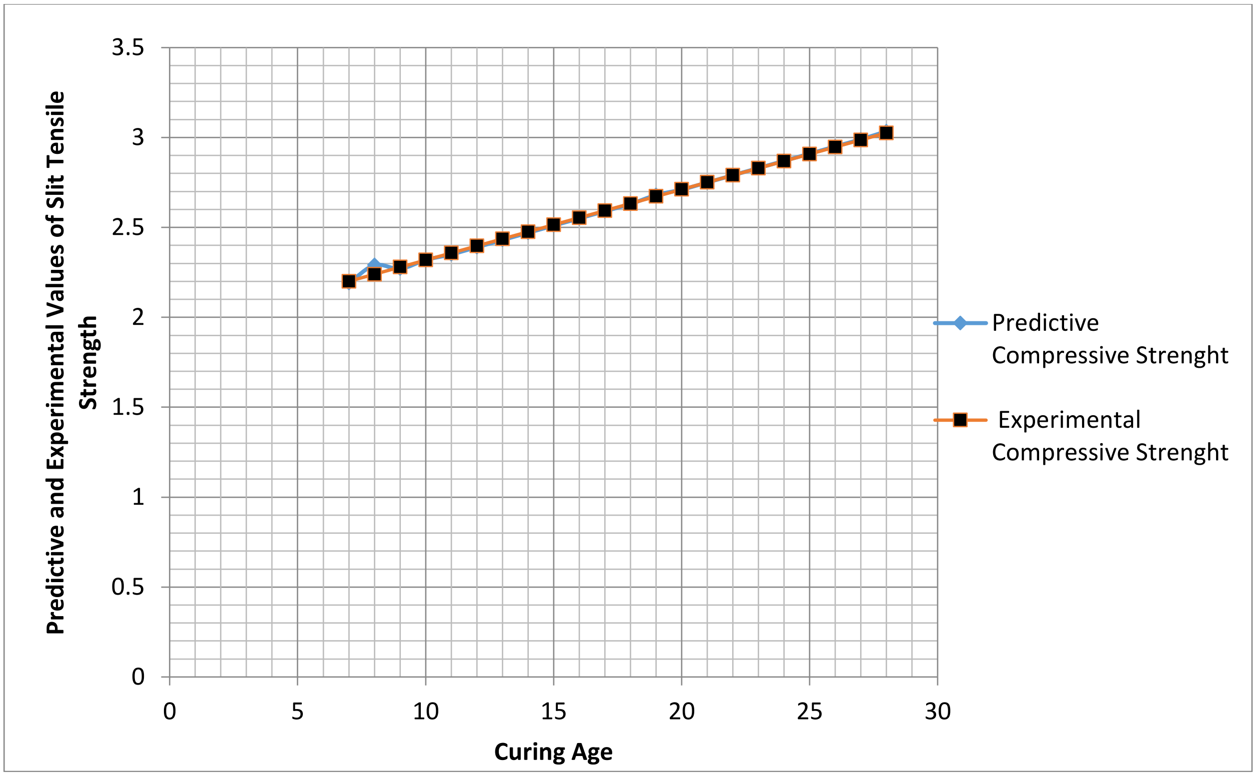

Figure 7: Predictive and Experimental of Split Tensile Strength at Different Curing Age

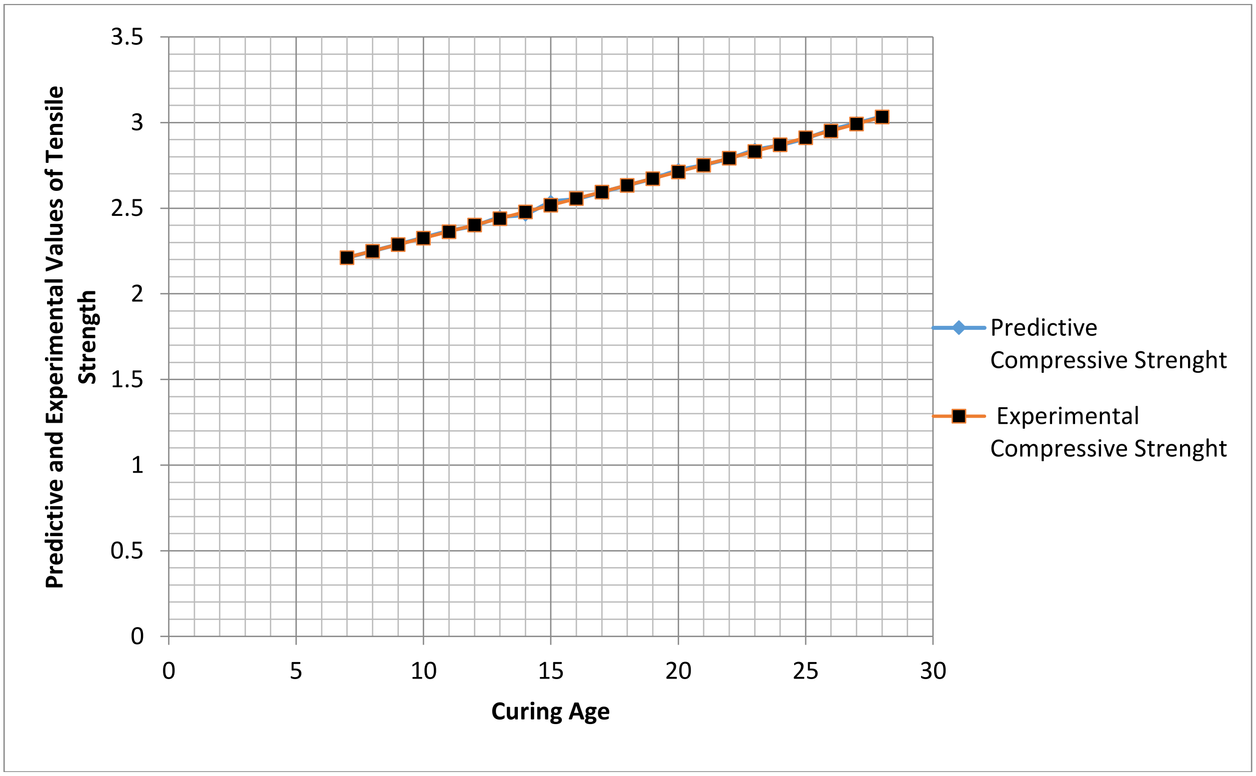

Figure 8: Predictive and Experimental of Split Tensile Strength at Different Curing Age

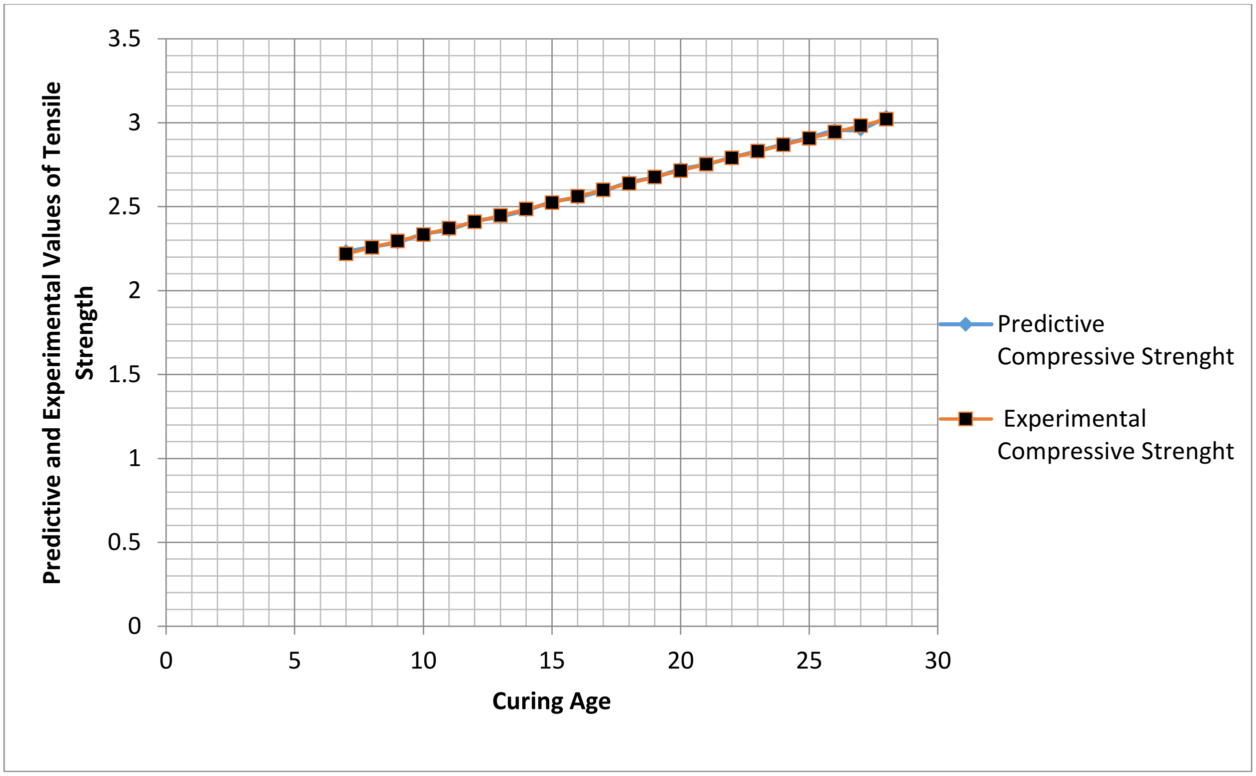

Figure 9: Predictive and Experimental of Split Tensile Strength at Different Curing Age

The study has expressed the behaviour of split tensile strength at various curing age modified with Super Plasticizers and fly Ash as an addictive's to increase the self-compacting concrete strength. The variation of curing were monitored on split tensile for self-compacting at interval of seven days and twenty four hours, fig. 3-4 explain the rates of fluctuation on an exponential phase were increase of split tensile strength experiences seven days interval. these predictive and experimental values observed close fits, some days that fluctuation were observed are due to the placement of concrete, split tensile strength reduces with increase in the water/powder ratio, but study was to monitor the behaviour applying these concept, these techniques is to monitor the behaviour of change in split tensile with respect to curing age at seven day interval, similar condition were experienced in fig. 5-6 were increase in split tensile were observed thus predictive and experimental values experienced close fits, but slight fluctuation were observed to the optimum at twenty eight days, curing age against split tensile were developed to observed the rate of influence from these addictive's applied to achieved higher compacting strength, while fig.7-9 experienced linear increase to the optimum rate of tensile strength, the comparison between the predictive and experimental expressed higher percent of closed fits

5. Conclusion

The study of predicting split tensile strength from self-compacting concrete modified with addictive's were carried to observed the actual behaviour on this parameters in the system. It is noted that the split tensile at every seven days interval decrease with increase on water/powder, but the focus of the study is to determine the behaviour of split tensile strength against curing age, this was to express the impact of tensile on modified concrete materials, the prediction of tensile strength through analytical and numerical were carried out to evaluate the increase of tensile in self-compacting concrete with variation of curing age. Several mix properties were observed to have influenced the variation of split tensile in the system, several experts may have not observed these dimension on the split tensile behaviour in concrete properties. The predictive model were subjected to simulation were the behaviour of split tensile at seven days interval and every day interval were thoroughly expressed from the graphical representations, the increase of water/powder ratio were observed to developed its variation of impact on the tensile strength in this concrete formation.

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