RELIABILITY STUDIES ON THE HYSTERESIS BEHAVIOUR OF MASS CONCRETE MIXED WITH PLASTIC FIBRE UNDER COMPRESSION

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ABSTRACT

The research work entails studying the reliability state of mass concrete mixed with plastic fibre under compression. Concrete is known to be a comparative brittle material when unreinforced, thus when concrete is reinforced with fibre, the compressive strength of the composite system increases. However, with additional loading, the fibre reinforcing will be activated, to hold the concrete mix together. This study investigated the effect of plastic fibre on compressive strength of Plastic Fibre Reinforced Concrete (PFRC) at 1:2:4 nominal mixes at different percentages of plastic fibre. The mix proportion was 1: 2: 4 with water cement ratio of 0.7. The slump was found to be 162 mm. PFRC cubes used were cast in 100 x 100 x 100 moulds. All samples were cured in water and tested for 7, 14, and 28 curing age. The density of PFRC increased with curing age which implies that during curing concrete absorbs water which aid its hydration The samples were crushed to determine the compressive strengths. The results of the study show that PFRC has an average compressive strength ranging from 25.6N/mm^2 to 36.1N/mm^2. The reliability index at 100years for the compressive strength of 0%, 0.1%, 0.2%, and 0.3% of PFRC is 0.6889, 0.7124, 0.6922 and 0.693 respectively. This indicates that PFRC has high reliability index

Keywords: Reliability index, Density, Compressive Strength, Plastic Fibre Reinforced Concretes

1.0 INTRODUCTION

Fibre-reinforced concrete is the concrete incorporated with short fibres so as to improve the property of the material. The introduction of fibres is brought in as a solution to increase the ductility of the concrete matrix. Fibres provide the brittle concrete with a post-cracking strength concrete with enhanced flexural and tensile strength. Fibres are used to improve the overall behaviour at the Ultimate Limit State where they can partially or totally substitute conventional reinforcement. (Gharpure*et al*, 2010). Fibres are also used to improve the behaviour in the Serviceability Limit State since they can reduce crack spacing and crack width, thereby improving durability and robustness. Fibres are most generally discontinuous, randomly distributed throughout the cement matrices. According to terminology adopted by the American Concrete Institute (ACI) Committee 544, in Fibre Reinforced Concrete, there are four categories namely, SFRC – Steel Fibre Reinforced Concrete, GFRC – Glass Fibre Reinforced Concrete, SNFRC – Synthetic Fibre Reinforced Concrete and NFRC – Natural Fibre Reinforced Different fibres differently affect the properties of concrete. Addition of synthetic fibres prevents cracking caused by plastic shrinkage and plastic setting, and provides tensile strength in the initial phase of hardening.

Plastic fibre shave recently been introduced in the field of reinforcement and are still in the development phase. It is considered that the contribution of plastic fibres in increasing the static strength of concrete is limited. A Plastic material is any of a wide range of synthetic or semi synthetic solids that are mouldable. Plastics are typical organic polymer of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petrochemical, but many are partially natural.

2.0 LITERATURE SURVEY

Reliability can be defined as the ability of an item to be able to perform an operation or a specific task or a unit operation without failure.

Reliability can also be defined as the complement of the probability of failure. i.e.

$$P_r(Success) = 1 - P_r(Failure) \qquad (1)$$

In reliability, safety is measured in terms of probability of uninterrupted operations. It is impossible to have an absolutely safe structure; because every structure has a certain non-zero probability of failure. Therefore, optimum level of safety has to be determined. Reliability finds suitable application in buildings, bridges, steel construction, soil engineering or geotechnical engineering, water flow, etc.

2.1 STRUCTURAL IMPORTANCE OF FIBRE REINFORCED CONCRETE

The inclusion of fibres in concrete is to delay and control the tensile cracking of Composite material and to change failure mode by means of improving post-cracking ductility, (Balaguru et al 1992). Also, Fibres are intended to improve flexural strength, toughness and impact strength (Bairagi et al 2001). Plastic Fibres thus transform inherent unstable tensile crack propagation to a slow controlled crack growth. This crack controlling property of plastic fibre reinforcement delays the initiation of flexural and shears cracking. It imparts extensive post cracking behaviour and significantly enhances the ductility and the energy absorption capacity of the composite (Ziab et al 1989)

Fibre reinforced concrete has started to find its place in many areas of civil Infrastructure applications where there is need for increased durability. Also, FRC is used in civil structures where corrosion can be avoided at the maximum. Hence, recent researches aim at increasing the energy absorption capacity and toughness of the material, as well as the tensile and flexural strength of concrete since the incorporation of fibre can cause a change in the failure mode under compressive deformation from brittle to pseudo-ductile, thereby imparting a degree of toughness to concrete. (Kandasamy et al 2011)

2.2 ENVIRONMENTAL SIGNIFICANCE OF PLASTIC FIBRE

One of the main environmental problems today is the disposal of the waste plastics. The use of plastics in various places as packing materials and the products such as bottles, polythene sheets, containers, packing strips etc., are increasing day by day. This results in production of plastic wastes from all sorts of livings from industrial manufacturers to domestic users. To circumvent this pollution crisis, many products are being produced from reusable waste plastics.

The plastic is one of the recent engineering materials which have appeared in the market all over the world. Some varieties of naturally occurring thermoplastics were known to Egyptians and Romans who extracted and used these plastics for various purposes. Plastics were used in bath and sink units, corrugated and plain sheets, floor tiles, joint less flooring, paints and varnishes and wall tiles. Other than these, domestically plastics were used in various forms as carry bags, bottles, cans and also in various medical utilities. There has been a steep rise in the production of plastics from a mere 30 million kN in 1955, it has touched 1000 million kN at present. It is estimated that on an average 25% of the total plastic production in the world is used by the building industry. The per capita consumption of plastics in the developed countries ranges from 500 to 1000N while in our country, it is only about 2N. There is however now increase in awareness regarding the utilization of plastic as a useful building material in our country. These types of usages normally generate more amounts of wastes which are to be disposed off properly. Environmentally sensitive aware people condemn the use of plastics for amount of pollution caused by them in disposal. However this is not a serious problem in comparison to the waste and pollution generated by a host of other industries. Reengineered plastics are used for solving the solid waste management problems to great extent. This study attempts to give a contribution to the effective use of waste plastics in concrete in order to prevent the ecological and environmental strains caused by them, also to limit the high amount of environmental degradation.

2.3 SOME RECENT DEVELOPMENTS IN FIBRE REINFORCED CONCRETE

The newly developed FRC named as Engineered Cementitious Composite (ECC) is 500 times more resistant to cracking and 40 per cent lighter than traditional concrete. ECC can sustain strain-hardening up to several per cent strain, resulting in a material ductility of at least two orders of magnitude higher when compared to normal concrete or standard fibre reinforced concrete. ECC also has unique cracking behaviour. When loaded to beyond the elastic range, ECC maintains crack width to below 100 μm, even when deformed to several per-cent tensile strains. Recent studies performed on a high-performance fibre-reinforced concrete in a bridge deck found that adding fibres provided residual strength and controlled cracking

2.4 RELIABILITY EVALUATION

Reliability is the probability that unsatisfactory performance or failure will not occur (Abdulraheem, 2016). Reliability, R (t), of the PFRC is defined as the probability that PFRC will perform its function over a specified period of time provided that other specified service conditions are met. According to Ajamu (2013), reliability predictions are used to evaluate design feasibility, compare design alternatives, identify potential failure areas, trade-off system design factors, and track reliability improvement. The strength analysis of the experimental results was carried out by considering a total/cumulative strength of 10 N/mm^2. Concrete structure service life as stated by European Standard, EN 1990 is 10 years for temporary structures, 50 years for buildings and other common structures and 100 years for monumental buildings, bridges and other special structures. A service life of 100 years was assumed and that other serviceability conditions are met.

Adedeji (2008) carried out reliability evaluation based on compressive strength of earth wall with respect to its service life. Specimens of cement plastered earth prism were constructed from bricks size 75mm x 105mm x 205mm. The specimen prisms have slenderness (height/thickness) ratio of 3 and were produce from bricks that were joined together using mix ratio of 1:10 of cement and sand. He carried out compressive strength at 3, 7, 14 and 28 days and the rate of strength gained for the tested specimen were obtained.

From the results of the analysis, the total strength considered was 100N/mm^2. If is the number of the strength by the end of testing day (i), then R_i is the total of the strength still remained at the end of day (i), and by Leitch (1988),

$$Q_i = \sum_{j=1}^{i} (\sigma_i) \tag{2}$$

$$R_i = 100 - Q_i \tag{3}$$

$$\lambda_i = \frac{\sigma_i}{R_{i-1}} \tag{4}$$

2.5 FAILURE RATES

Reliability predictions are based on failure rates. A failure rate can be defined as the anticipated number of times an item will fail in a specified time period. It is a calculated value that provides a measure of reliability for a product. This value is normally expressed as failures per million hours (FPMH), but can also be expressed as failures per billion hours. Failure rate calculations are based on component data such as temperature, environment, and stress. In the prediction model, assembly components are structured serially.

Thus, calculated failure rates for assemblies are a sum of the failure rates for components within the assembly (ITEM ToolKit 2012).

2.6 CONSTANT FAILURE RATE MODEL

According to Leitch (1988), reliability index using constant failure rate (CFR) model is as given in equation (8) and λ is assumed constant with time.

$$R(t) = e^{-\lambda t} \quad (5)$$

Where R(t) = reliability index, λ = constant rate of failure, t = variable time . The failure density is expressed with respect to constant rate of failure as:

$$F(t) = \lambda e^{-\lambda t} \quad (6)$$

So that the estimator is expressed as recommended by Leitch (1988):

$$F(t) = 1 - e^{-\lambda t} \quad (7)$$

The mean time to failure (MTTF) is the average functioning (without a failure) period for an item or average life cycle of a number of items, is expressed as:

$$MTTF = \frac{1}{\lambda} \quad (8)$$

So that reliability:

$$R(t) = e^{-\frac{t}{MTTF}} \quad (9)$$

MEAN TIME TO FAILURE (MTTF)

MTTF is a basic measure of reliability for non-repairable systems. It is the mean time expected to the first failure of a piece of equipment. MTTF is a statistical value and is meant to be the mean over a long period of time and large number of units. For constant failure rate systems, MTTF is the inverse of the failure rate. If failure rate is in failures/million hours, MTTF = 1,000,000 / Failure Rate for components with exponential distributions (ITEM ToolKit 2012).

3.0 MATERIALS AND METHODOLOGY

MATERIALS

The materials comprise of cement, sand, granite,plastic fibre Straw and water,

LABORATORY TEST RESULTS

Sieve analysis, specific gravity, water absorption capacity of coarse aggregate Test was done according ASTM D422 62 and ASTM C1884.

PREPARATION OF PLASTIC FIBRE (STRAW)

Plastic straw was used as the fibre with an average length of 29cm, it was cut into small chips of about 3cm and then mixed with Concrete which was poured into moulds.

CONCRETE SLUMP

In the slump test, a mould shaped as the frustum of a cone, 305mm high with 203mm diameter base and 102mm diameter top was filled with PFRC in 3layers and subjected to 25 strokes of tamping rod each (ASTM Specification C143). Immediately after filling, the mould was removed and the change in height of the specimen was measured. The change in height of the specimen was taken as the slump when the test is done according to the ASTM Specification.

CASTING OF TEST SPECIMENS

The mix proportion was 1: 2: 4 with water cement ratio of 0.7. The fine aggregate used was natural river sand. The coarse aggregate used was crushed stone passing IS 20 mm sieve and retained on 4.75 mm sieve. Potable water of pH value 6.72 was used. The test consisted of arriving at mix proportions, weighing the ingredients of concrete accordingly, mixing them in a standard concrete mixer and then testing for the fresh properties of respective concrete. 24 Standard cubes of dimensions 100 mm x 100 mm x 100 mm were cast to check whether the target compressive strength was achieved at 7days, 14-days and 28- days curing. The standards moulds were fitted such that there are no gaps between the plates of the moulds. The moulds were then lubricated and kept ready for casting. After 24 hours of casting, the specimen were de-moulded and transferred to curing tank where they were immersed in water for the desired period of curing.

CURING

The curing technique that was applied was Water Submerged Curing (WSC) which involves the submersion of the concrete cube specimens in water. The plastic fibre reinforced concrete was cured for 7, 14, and 28 days.

COMPRESSIVE STRENGTH TEST

The compressive strength of each plastic fibre reinforced concrete was tested using the compressive testing machine. Cubes for each age and each percentage were crushed and the Compressive Strength was obtained using equation 10.

$$\text{Compressive Strength} = \frac{Crushing\ load\ (KN)}{Area\ of\ cube (mm2)} \text{-------------} \quad (10)$$

RELIABILITY ANALYSIS

The reliability of PFRC as a function of time (years) was evaluated. The constant rate failure (CFR) method was used in evaluating the reliability index of PFRC. The strength analysis of compressive strength of PFRC were computed using equation 3.2. Assuming a service life of 100 years with other serviceability conditions are met.

$$\text{Reliability} = e^{-\lambda t} \quad (11)$$

Where: $\lambda = \frac{1-d}{T}$

$T = time\ (years), \quad the\ expected\ life\ span\ of\ the\ wall$

$d = average\ strength\ rate$

$\lambda = failure\ rat$

4.0 RESULTS AND DISCUSSION

SIEVE ANALYSIS

Result shows that the sieve analysis and the trend of the percentage cumulative weight retained increases as the sieve sizes decrease.

WATER ABSORPTION CAPACITY

The water absorption capacity of the coarse aggregate was found to be 10%. This value was considered in the design of mix in other to achieve the appropriate nominal mix to avoid excess use of water in concrete mixes.

SLUMP TEST AND WATER-CEMENT RATIO

Results show that the slump of PFRC increased with increase in water cement ratio. That is, the nominal mix exhibited the least slump of 150mm which falls on 0.3 w/c ratio, while the highest slump is 162mm obtained for w/c ratio of 0.7. This means that 0.3w/c ratio is well proportioned hence it settles slowly and retains its original shape, conforming the usage of plastic fibre reinforced concrete for mass concrete at 1:2:4 nominal mix.

DENSITY

The density of the PFRC also increases with curing age, which implies that during curing, concrete absorbed water which aids the hydration. The density of the specimens ranged from 2473 to 2532*Kg/m3*. This lies within the range of 2200 to 2600 *Kg/m3* specified as the density of normal weight concrete (Neville, 2000).

COMPRESSIVE STRENGTH

Compressive strength of plastic fibre reinforced concrete increased with increase in curing age. Compressive strength increases for all dosage of fibres, this is due to confinement provided by fibre bonding characteristics of concrete increases and hence compressive strength increases with the increases in the fibre content and the target mean of 20mpa was achieved as the minimum compressive strength was 25.6N/mm2 at 7 days, this which is more than the target mean.The Average weight, density and compressive strength are shown in Table 1.

Table 1: Average Weight, Density and Compressive Strength of PFRC

S/N	%PFRC	Age	Average Weight (g)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)
1	0	7	2473	2473	256.0	25.60
2	0	14	2495	2495	318.9	31.89
3	0	28	2525	2525	334.3	33.43
4	0.1	7	2479	2479	265.8	26.58
5	0.1	14	2493	2493	323.0	32.30
6	0.1	28	2528	2528	344.0	34.40
7	0.2	7	2485	2485	280.2	28.02
8	0.2	14	2498	2498	328.9	32.89
9	0.2	28	2530	2530	350.6	35.06
10	0.3	7	2490	2490	294.0	29.40
11	0.3	14	2514	2514	337.0	33.70
12	0.3	28	2532	2532	361.3	36.13

RELIABILITY ANALYSIS OF STRENGTH RESULTS

A reliability evaluation based on the compressive of PFRC with respect to its service life was carried out. The strength analysis of compressive strength of PFRC were computed. Assuming a service life of 100 years with other serviceability conditions are met. The Strength analysis of the compressive strength of the different percentages of plastic fibre ranging from 0 – 0.3% is shown in Table 2, 4, 6, and 8 respectively. The reliability indices of the different percentages varying 0 % - 0.3 % is also shown in Table 3, 5, 7 and 9 respectively

Table 2: Strength Analysis of Compressive Strength of 0% Plastic Fibre

Days	Average Strength (σ) (N/mm^2)	Cumulative strength (Q_i) (N/mm^2)	Remaining strength (Ri) %	Strength Rate (d_i)
7	25.6	25.60	65.32	0.39
14	31.89	57.49	33.43	0.49
28	33.43	90.92	0	1

The average strength rate, d = $\frac{0.39+0.49+1}{3} = 0.6273$

$$\lambda = \frac{1 - 0.6273}{100} = 0.003727\text{year}$$

Table 3: Reliability Using CFR

Time, t (years)	λt	$e^{-\lambda t}$	Time, t (years)	λt	$e^{-\lambda t}$
0	0	1	180	0.6709	0.511
20	0.0745	0.928	200	0.7454	0.4745
40	0.1491	0.861	220	0.8199	0.4404
60	0.2236	0.800	240	0.8945	0.4088
80	0.2982	0.7421	260	0.9690	0.3795
100	0.3727	0.6889	280	1.0436	0.352
120	0.4474	0.6393	300	1.1181	0.3269
140	0.5938	0.5522	320	1.1926	0.3034
160	0.5508	0.5765	340	1.267	0.2816

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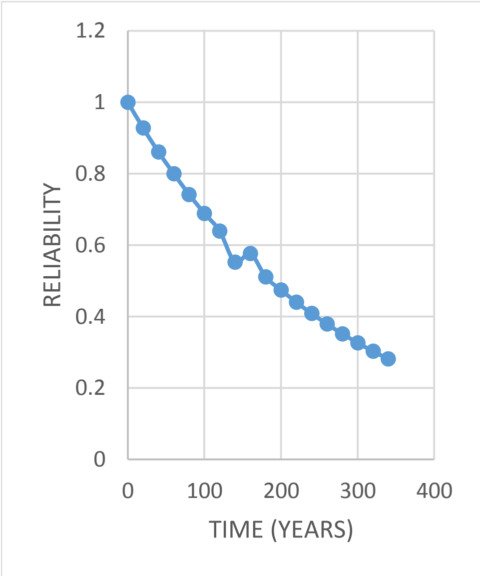

Figure 1: Graph of Reliability of Compressive strength of 0 % Plastic Fibre

Days	Average Strength (σ) (N/mm^2)	Cumulative strength (Q_i) (N/mm^2)	Remaining strength (Ri) %	Strength Rate (d_i)
7	26.58	26.58	66.7	0.3985
14	32.30	58.88	34.4	0.5842
28	34.40	93.28	0	1

Time, t (years)	**λt**	$e^{-\lambda t}$	**Time, t (years)**	**λt**	$e^{-\lambda t}$
0	0	1	180	0.6104	0.5431
20	0.06782	0.9344	200	0.6782	0.5075
40	0.1356	0.8732	220	0.7460	0.4743
60	0.2035	0.8158	240	0.8138	0.4432
80	0.2712	0.7624	260	0.8817	0.4141
100	0.3391	0.7124	280	0.9495	0.3869
120	0.4069	0.6657	300	1.0173	0.3617
140	0.4747	0.6221	320	1.0851	0.3379

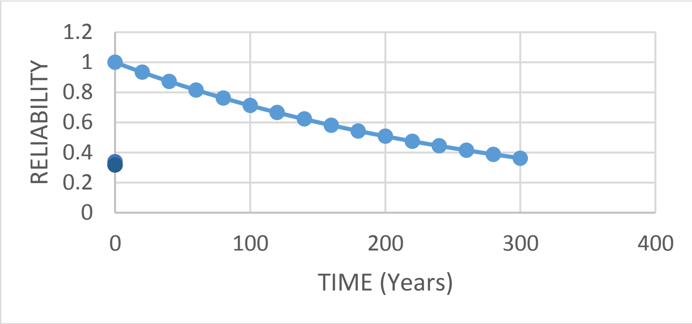

Figure 2: Graph of Reliability of Compressive strength of 0.1% Plastic Fibre

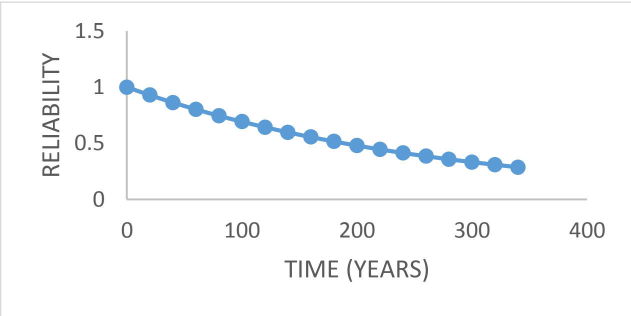

Figure 3: Graph of Reliability of Compressive strength of 0.2% Plastic Fibre

Table 4: Strength Analysis of Compressive strength of 0.1 % Plastic Fibre

The average strength rate, d = $\frac{0.3985+0.5842+1}{3}$ = 0.6609

$$\lambda = \frac{1 - 0.6609}{100} = 0.003391/year$$

Table 5: Strength Analysis of Compressive strength of 0.2% Plastic Fibre

160	0.5426	0.5812	340	1.1529	0.3157

At 100 years, the reliability index is 0.7124

Table 5 : Reliability Using CFR

Days	Average Strength (σ) (N/mm^2)	Cumulative strength (Q_i) (N/mm^2)	Remaining strength (Ri) %	Strength Rate (d_i)
7	28.02	28.02	67.95	0.4123
14	32.89	60.91	35.06	0.484
28	35.06	95.97	0	1

The average strength rate, d = $\frac{0.4123+0.484+1}{3} = 0.6321$

$$\lambda = \frac{1 - 0.6321}{100} = 0.003679/\text{year}$$

Table 6: Reliability Using CFR

Time, t (years)	**λt**	**$e^{-\lambda t}$**	**Time, t (years)**	**λt**	**$e^{-\lambda t}$**
0	0	1	180	0.662	0.5157
20	0.0736	0.9291	200	0.735	0.4791
40	0.1472	0.8631	220	0.809	0.4451
60	0.2207	0.8020	240	0.883	0.4135
80	0.2943	0.7450	260	0.956	0.3842
100	0.3679	0.6922	280	1.030	0.3570
120	0.4415	0.6431	300	1.103	0.3316
140	0.5151	0.5974	320	1.177	0.3081
160	0.5886	0.5551	340	1.250	0.2862

At 100 years, the reliability index is0.6922

Time, t (years)	λt	$e^{-\lambda t}$	Time, t (years)	λt	$e^{-\lambda t}$
0	0	1	180	0.6588	0.5174
20	0.0732	0.929	200	0.732	0.481
40	0.1464	0.864	220	0.8052	0.447
60	0.2196	0.803	240	0.8784	0.4154
80	0.2928	0.746	260	0.9516	0.3861
100	0.366	0.693	280	1.0248	0.3589
120	0.4392	0.645	300	1.098	0.3335
140	0.5124	0.5991	320	1.1712	0.310
160	0.5856	0.5568	340	1.2444	0.2881

Table 7: Strength Analysis of Compressive strength of 0.3% Plastic Fibre

Days	Average Strength (σ) (N/mm^2)	Cumulative strength (Q_i) (N/mm^2)	Remaining strength (Ri) %	Strength Rate (d_i)
7	29.4	29.4	69.83	0.421
14	33.7	63.1	36.13	0.483
28	36.13	99.23	0	1

The average strength rate, d = $\frac{0.421+0.483+1}{3} = 0.634$

$$\lambda = \frac{1 - 0.634}{100} = 0.00366/year$$

Table 8: Reliability Using CFR

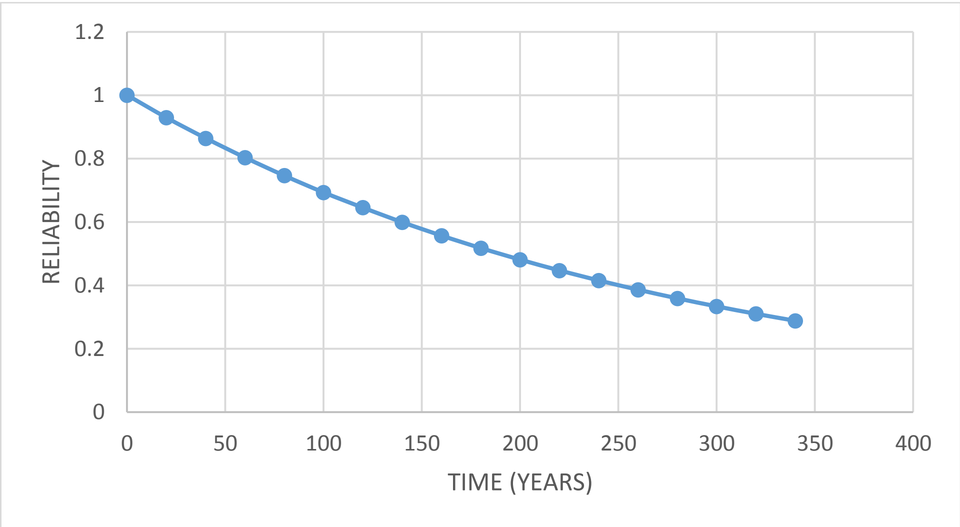

Figure 4: Graph of Reliability of Compressive strength of 0.3% Plastic Fibre

At 100 years, the reliability index for the compressive strength of 0%,0.1%,0.2%, 0.3% of PFRCis 0.6889, 0.7124, 0.6922 and 0.693respectively. Reliability coefficientsrange from 0.00 to 1.00, with highercoefficients indicating higher levelsof reliability which indicates that PFRC has high reliability index especially at 0.1 % of plastic fibre.

CONCLUSION

1. The density of the specimens ranged from 2473 to 2532 *Kg/m3*. This lies within the range of 2200 to 2600 *Kg/m3* specified as the density of normal weight concrete (Neville, 2000). Based on the density, the specimens fall into the category of normal weight concrete.
2. The compressive strength of concrete used in construction for general use in construction must be at least 20mpa, the plastic fibre concrete can thus be used since the minimum obtained is 25.6mpa.
3. The range of compressive strength obtained is between 25.6-36.3 thus the concrete can be used for applications where surface spalling is not acceptable, and significant loading is expected. One example is paving curbs, building footings, bond beams, grade beams, and floor slabs.
4. At 100 years, the reliability index for the compressive strength of 0%, 0.1%, 0.2%, 0.3% of PFRC is 0.6889, 0.7124, 0.6922 and 0.693 respectively. Reliability coefficients range from 0.00 to 1.00, with higher coefficients indicating higher levels of reliability which indicates that PFRC has high reliability index. This implies that PFRC is a reliable concrete that can function satisfactorily for 100 years.
5. Reliability of the PFRC decreased with age at the different percentages of plastic fibre

RECOMMENDATION

Plastic fibre waste should be used in order to reduce or totally eradicate environmental pollution.

REFERENCES

Abdulraheem, K.K. (2016). "Reliability Index Assessment of Solid and Laminated Teak Wooden Deep I – Beam for Residential Building". M.Eng. Project Report Submitted to the Department of Civil Engineering, Faculty of Engineering and Technology. University of Ilorin

Adedeji A.A. (2008). "Reliability-Based Probability Analysis for Predicting Failure of Earth Brick Wall in Compression". Nigerian Journal of Construction Technology and Management. 9(1), 25 – 34.

Ajamu, S.O. (2014). "Optimal design of cement-lime plastered straw bale masonry under vertical load and thermal insulation for a residential building". Ph.D Thesis Report Submitted to the Department of Civil Engineering, Faculty of Engineering and Technology. University of Ilorin.

BS EN 12350 – 2. (2000). "Testing Fresh Concrete – Part 2: Slump Test". British Standards Institution. London, UK.

BS EN 12390 - 3. (2002). "Testing Hardened Concrete – part 3: Compressive Strength of Test Specimens". British Standards Institution.

Banthia N., Gupta R., and Mindess S.,(2004) Developing crack resistant FRC overlay materials for repair applications, NSF Conference, Bergamo, Italy.

Banthia, N., (2004). Impact and Blast Protection with Fibre Reinforced Concrete, Conference Proceedings - *BEFIB, Veronna, Italy, RILEM*, 39, pp. 31-44;

Banthia N., and Sheng J. (1996) "Fracture Toughness of Micro- Fibre Reinforced Cement Composites", Cement and Concrete Composites, 18 (1), 251-269.

Banthia N. (2008) "Fibre Reinforced Concrete" University of British Columbia, Vancouver, Canada. 1-5.

Bairagi N.K and Modhera C.D (2001) "Shear Strength reinforced concrete", ICI Journal, Jan-March, 2(1), 47-52.

Balaguru P.N, and Shah S.P. (1992), Fibre-Reinforced Cement Composites, Singapore, McGraw-Hill.

Bhargava, A. and Banthia, N. (2008). *RILEM, Materials and Structures*, 41: 363-372.

Brown R., Shukla A. and Natarajan K.R. (2002), fiber reinforcement of concrete structures, University of Rhode Island, 2-22.

Efunda, (2011) "Reliability" (www.Efunda.com/math/reliability/reliability.cfm)

ITEM ToolKit Version 3.0.6 Software © 2012 "ITEM ToolKit Getting Started Tutorial" www.itemsoft.com

Leitch, R. D, (1988). "Basic reliability engineering analysis", 1st Edition, McGinley, 13-86

Neville, A. M. (1996). *Properties of Concrete,* 4th ed., USA, New York: John Wiley and Sons

KandasamyR. and MurugesanR.,"Fibre reinforced concrete using domestic Waste plastics as fibres", ARPN Journal of Engineering and Applied Sciences 6(3)

Prabir Das, (2004), "Engineering Plastics: New Generation Products for Building and Construction," CE&CR, . 38-40.