NUMERICAL COMPARATIVE ANALYSIS OF COCONUT FIBRE COMPOSITE CONCRETE (CFCC) AND LATHE STEEL WASTE COMPOSITE CONCRETE (LSWCC) UNDER BLAST LOADINGS

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Abstract: This work is a comparative analysis of the blast resistance capability of coconut fibre composite concrete (CFCC) and lathe steel waste composite concrete (LSWCC) using finite element numerical analysis. The static compressive, splitting tensile and flexural strength of CFCC and LSWCC were experimentally determined using a range of 0 to 2% by volume of fibre reinforcements. Both CFCC and LSWCC exhibited optimum strength characteristics at 1.5% of fibre reinforcements. The dynamic numerical analysis shows clearly that both LSWCC and CFCC reduced the displacement considerably compared to plain concrete and more importantly, LSWCC performed better than CFCC in displacement reduction. It is also noted that the peak values of acceleration, velocity, shear force and moment occurred at 1.5% volume fibre content for both LSWCC and CFCC. However, LSWCC exhibited more energy absorption capacity than CFCC as reflected in the acceleration, velocity, moment and shear resistances.

Keywords: Blast loading, coconut fibre, dynamic response, lathe steel

Introduction

Concrete has good compressive and low tensile strength. Addition of fibre into concrete improves its matrix composition with the provision of confinement to the molecular structure leading to improved performance in tension and shear. In dynamic realm, the response of composite concrete has not been exhaustively investigated because of the complexity of experimental methodology. However, numerical computation using finite element method of analysis has proven to be useful for the prediction of the dynamic response of composite concrete structural elements. This is necessary because of the incessant terrorist attacks across the continents and more particularly in the developing world like Nigeria.

Although a lot of work has been carried out on steel scrap reinforced concrete under static loading but not much has been done on the dynamic response. The same is true for the coconut fibre reinforced concrete.Although limited numerical dynamic work has been done on both reinforcing materials as reported by Ashore (2016) and Ajayi (2016), and that has formed the basis for comparison of LSWCC and CFCC in terms of their performance. It is imperative for more work to be done to establish how these fibre reinforced concretes will behave under blast loading both numerically and experimentally. According to Li &Hao (2013 & 2014), conventional concrete is highly brittle and suffers total damage under blast loadings.

Generally, the addition of dispersed short fibrous materials into concrete matrix is a way to improve survivability of concrete structures in a blast environment as observed by Mutalib&Hao (2011). Wu *et al*. (2007) and Xiao &Lok (1999) independently carried out experiments on a one way simply supported and a two way steel fibre-reinforced concrete (SFRC) panels under varying blast loads. The panels were reinforced with hooked end steel fibre at fibre content ranging from 0.5 to 1.5% and aspect ratios varying between 33 and 75. The panels were subjected to hemispherical blast waves from detonation of varying trinitrotoluene (TNT) charge weight. They reported that SFRC panels exhibited improved damage tolerance to blast loading. It was also observed that as the fibre content increased from 0.5 to 1.0%, there was a reduction in the residual displacement. Similar observations using SFRC slabs were reported by Lan*et al.* (2005) and they noted that 1.0% fibre concentration is optimum in resisting damage. In addition, they concluded that long fibre performed better than the short fibre in resisting cracking and spalling. Xu*et al.* (2012) concluded that spiral-shaped steel fibres added to concrete matrix improved the compressive strength, post-failure strength and high energy absorption capacity. Several investigations into the effects of blast loadings on concrete, including both experimental and numerical studies have been reported in the open literature. Such authors include but not limited to Silva & Lu (2009), Tai *et al*. (2011), Wang *et al.* (2013), Zhao & Chan (2013) and Pantelides*et al.* (2014). The aim of this work is to investigate the dynamic behavior response of lathe steel waste concrete using finite element method with the experimentally determined dynamic strength characteristics.

The impact tests on various biological fibre (coconut, sisal, jutes, hibiscus and cannabis) reinforced concrete slabs reported by Seong*et al*. (2015) show clearly that coconut fibre performed better than others in energy absorption. The observation was made by Ramakrishna &Sundarajan (2015) that the energy absorption capacity of CFRC exceeded that of plain concrete. It has been reported that the addition of coconut fibre to concrete matrix improves its viscous damping leading to reduced natural frequency. This was reported by Wang &Chouw (2011) of their work on the varying contents of coconut fibre in concrete.

Materials and Methods

Material and mix proportions

Locally available Portland Cement Type II conforming to ASTM-C192 was used. Natural River sand of maximum particle size of 3.18 mm was used as fine aggregates and crushed granite (maximum size of 12 mm) obtained from local quarries as coarse aggregates. Portable water free from salts was used for casting and curing of concrete. Lathe steel waste fibres were obtained from the machining process of the lathe machine and the coconut fibres were collected from local source in the Lagos area of the Southwestern Nigeria. The fibre was mixed at varying percentages with concrete matrix of 1:2:4. The fibre contents between 0 and 2% at 0.5% step were considered. The fibres were added to the concrete matrix before being poured into the 150 x 150 mm and well compacted before being left to cure for 28 days.

Numerical method

A dynamic finite element method was used in analyzing the LSWCC and CFCC beams of 3 m long, with cross-section dimension of 100 x 200 mm fixed at both ends. Using details of a dynamic finite element analysis modeling as reported in Ashore (2016). A triangular blast load of maximum force of 500 kN and the decay time of 3 micro seconds for the positive phase. The beam is divided into 4 and 5 elements to study the sensitivity of the program to number of elements. It is observed that the differences in the computed results are insignificant. An elastic approached was employed with non-linear behavior accounted for in the form cracked concrete stress strain curve.

Results and Discussion

Dynamic modulus of elasticity computation

The computation of dynamic modulus of elasticity is based on the method proposed by Zhao & Chan 2013 and the results of the computation as shown in Table 1. Details of this method are presented in Ashore (2016) and Ajayi (2016), respectively and the computed data are presented in Table 1. The same data are presented graphically in Fig. 1.

Table 1: Dynamic modulus for LSWCC and CFCC

Fibre content (%)	LSWCC (MPa)	CFCC (MPa)
0	22931.83	22701
0.5	24317.09	22516
1	24675.83	21834
1.5	26939.11	22148
2	24352.67	21263

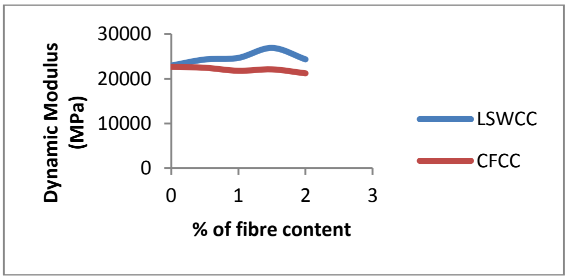

Fig. 1: Comparison of dynamic modulus of LSWCC and CFCC

Comparison of LSWCC with CFCC

The beam example analyzed has cross sectional dimension of 100 mm width, 200 mm height and 3000 mm length and fixed at both ends. The beam is modelled as beam element with 3 degree of freedom. The computed results for LSWCC and CFCC are compared as presented in the following Tables and Figures.

The comparison in Table 2 and Fig. 2 shows a lower acceleration for CFCC than that observed in LSWCC This clearly indicates that LSWCC has move viscous damping than CFCC which is the expected behavior because the density of LSWCC is more that of CFCC. This clearly will lead to better energy dissipation by the LSWCC than CFCC.

The comparison in Table 3 and Fig. 3 shows a lower velocity for LSWCC than that of CFCC. This is a reverse of the acceleration. This could be explained by the displacement observed for CFCC is far higher than that of LSWCC. The velocity is calculated based on the displacement and time interval.

Table 2: Comparison of LSWCC acceleration with CFCC

Fibre content (%)	LSWCC	CFCC
0	2.32E-02	1.88E-02
0.5	2.17E-02	2.17E-02
1	2.94E-02	2.22E-02
1.5	4.75E-02	2.82E-02
2	3.29E-02	2.62E-02
2.5	-	2.46E-02

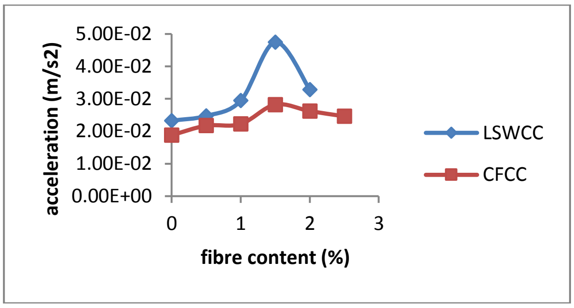

Fig. 2: Comparison of LSWCC acceleration with CFCC

Table 3: Comparison of LSWCC velocity with CFCC

Fibre content (%)	LSWCC	CFCC
0	7.34E-01	8.85E-01
0.5	7.96E-01	8.79E-01
1	7.54E-01	8.68E-01
1.5	7.43E-01	8.62E-01
2	7.43E-01	8.72E-01
2.5	-	8.83E-01

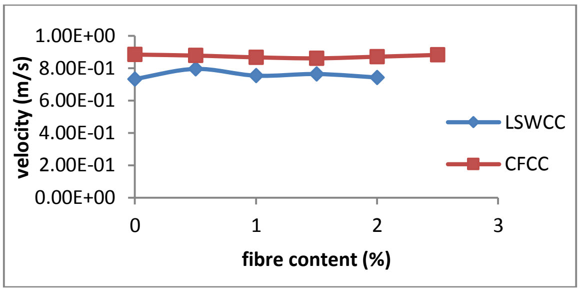

Fig. 3: Comparison of LSWCC velocity with CFCC

The comparison in Table 4 and Fig. 4 shows a lower displacement for LSWCC. This is clear indication of higher resistance of LSWCC than CFCC. LSWCC has more stiffness and viscous damping more than CFCC. This could be as a result of denser material consistent with the steel waste. Clearly, lower displacement signifies better energy dissipation by the LSWCC than CFCC.

The comparison in Table 5 and Fig. 5 shows a lower moment for CFCC than that observed in LSWCC this could be as a result of higher stiffness characteristics of LSWCC which attract more resulting forces. This also is a clear indication of better energy absorption by LSWCC.

Table 4: Comparison of LSWCC displacement with CFCC

Fibre content (%)	LSWCC	CFCC
0	9.39E+01	1.18E+02
0.5	9.58E+01	1.15E+02
1	9.30E+01	1.14E+02
1.5	8.19E+01	1.08E+02
2	8.99E+01	1.09E+02
2.5	-	1.12E+02

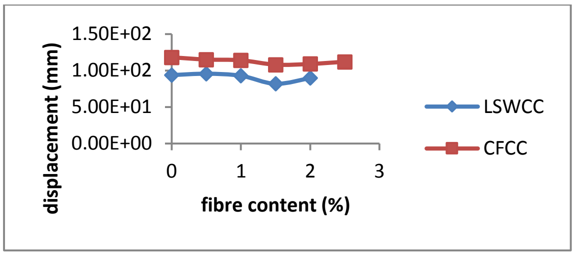

Fig. 4: Comparison of LSWCC displacement with CFCC

Table 5: Comparison of LSWCC moment with CFCC

Fibre content (%)	LSWCC	CFCC
0	1.02E-02	6.52E-03
0.5	9.98E-03	7.47E-03
1	1.22E-02	7.68E-03
1.5	1.86E-02	9.84E-03
2	1.24E-02	9.71E-03
2.5	-	8.43E-03

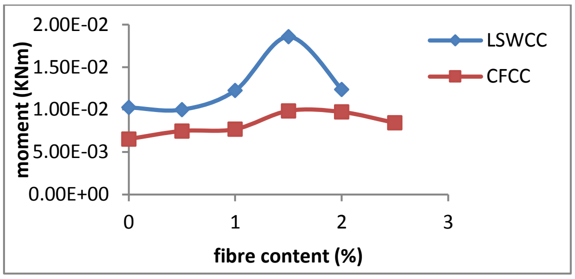

Fig. 5: Comparison of LSWCC moment with CFCC

Table 6: Comparison of LSWCC shear force with CFCC

Fibre content (%)	LSWCC	CFCC
0	1.42E-02	1.07E-02
0.5	1.60E-02	1.23E-02
1	1.79E-02	1.26E-02
1.5	3.05E-02	1.62E-02
2	2.11E-02	1.60E-02
2.5	-	1.39E-02

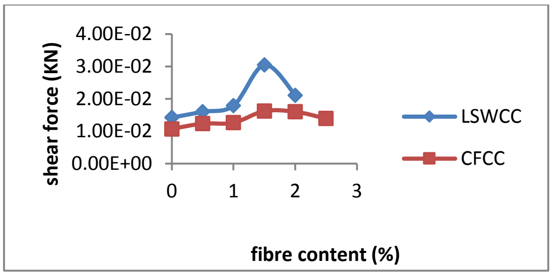

Fig. 6: Comparison of LSWCC shear force with CFCC

The comparison in Table 6 and Fig. 6 shows a lower shear force for CFCC than that observed in LSWCC. The same phenomenon could be attributable for shear as well as resulting moment.

Conclusion

The LSWCC is generally better material for the resistance of blast loading. Even though, this study is not exhaustive but there is clear indication that LSWCC has a better prospect in energy dissipation and absorption with lower displacement in the course of being exposed to blast loading

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