2017 2nd International Conference on Architectural Engineering and New Materials (ICAENM 2017)
ISBN: 978-1-60595-436-3

Finite Element Analysis of Flexural Tensile Property About Layered Steel Fiber Inorganic Polymer Lightweight Aggregate Concrete

Tianfu Liang and Yang Meng

ABSTRACT

Layered steel fiber structure can effectively improve the flexural strength and toughness of inorganic polymer lightweight aggregate concrete under the condition of less steel fiber content. The flexural tensile strength of steel fiber reinforced inorganic polymer lightweight aggregate concrete with steel fiber volume ratio of 0.9%, 1.2% and 1.5% increased by 35.44%, 38.52% and 40.03%, respectively. The flexural tensile strength of double deck steel fiber (upper layer 0.9%, lower layer 1.2%) increased by 39.24%. ABAQUS was used to simulate the flexural behavior of layered steel fiber inorganic polymer lightweight aggregate concrete. The finite element model can accurately calculate the bending strength of layered steel fiber reinforced inorganic polymer lightweight aggregate concrete beam, the calculated value of the ultimate load is in good agreement with the experimental results[1].

The flexural strength of concrete is an important index of pavement and bridge deck. Layered steel fiber reinforced concrete (LSFRC for short) is a certain thickness of concrete within steel fiber, and the rest is plain concrete. LSFRC can be obtained with steel fiber reinforced concrete with similar flexural strength, and greatly saves the cost by using small amount of steel fiber. Based on layered steel fiber reinforced inorganic polymer lightweight aggregate concrete (LSFIPLAC for short), the tensile strength and toughness also can be improved with lower cost [1-4].

[1]Tianfu Liang,Wuhan Metro Group Co., LTD, Hubei, China.
Yang Meng, School of Civil Engineering and Architecture, Wuhan University of Technology, Hubei, China.

SPECIMEN MIX RATIO

Table I show the mix ratio of specimen. Specimen size is 100mm×100mm×400mm, and table II shows the volume fraction of steel fiber.

TABLEI. EXPERIMENTAL MIX RATIO（KG/M^3）

Net water/kg	Cementing material/kg	Fine aggregate/kg	Lightweight aggregate/kg	Water to binder ratio	Volume sand ratio	Pre absorption
171	450	696	539	0.38	40%	1h

TABLEII. VOLUME FRACTION OF STEEL FIBER

Specimen number		IPLAC	LSF1	LSF2	LSF3	LSF4
Volume fraction of steel fiber/%	Upper	-	-	-	-	0.9
	Lower	-	0.9	1.2	1.5	1.2
Steel fiber content/g	Upper	-	-	-	-	56.16
	Lower	-	56.16	74.88	93.6	74.88

EXPERIMENTAL RESULT

Basic mechanical properties of inorganic polymer lightweight aggregate concrete (IPLAC for short) for 28 days are shown in table III.

TABLE III. BASIC MECHANICAL PROPERTIES OF IPLAC SPECIMENS.

Cube Strength/MPa	Axial compressive strength/MPa	Splitting tensile strength/MPa	Modulus of elasticity/GPa
43.7	37.0	2.97	25.34

The experimental procedure of flexural tensile test is based on CECS13:2009 standard for test method of fiber concrete and GB50081-2002 standard test method for mechanical properties of ordinary concrete. The test uses displacement control, and the loading speed is 0.002mm/s. The test results are shown in Table IV. The load displacement curve is shown in figure 1.

TABLE IV. EXPERIMENTAL RESULTS.

Specimen number	IPLAC	LSFIPLAC1	LSFIPLAC2	LSFIPLAC3	LSFIPLAC4
Flexural tensile strength/MPa	4.31	5.84	5.97	6.04	6
Increase ratio/%	100	135.44	138.52	140.03	139.24

From table IV, The flexural tensile strength of LSFIPLAC with steel fiber volume ratio of 0.9%, 1.2% and 1.5% increased by 35.44%, 38.52% and 40.03% respectively. The flexural tensile strength of double deck steel fiber increased by 39.24%.

FINITE ELEMENT ANALYSIS

STRESS STRAIN RELATIONSHIP OF IPLAC

Formula 1 is used in IPLAC compressive stress-strain constitutive equation. Formula 2 is used in IPLAC tensile stress-strain constitutive equation 3. The values of rising parameter α_a and falling parameter α_d adopt the values of literature [5].

$$\begin{cases} y = \alpha_a x + (3 - 2\alpha_a)x^2 + (\alpha_a - 2)x^3 & (0 \le x \le 1) \\ y = \dfrac{x}{\alpha_d (x-1)^2 + x} & (x > 1) \\ x = \varepsilon / \varepsilon_c, \ \ y = \sigma / f_c \end{cases} \tag{1}$$

$$\begin{cases} y = 1.2x - 0.2x^6 & (0 \le x \le 1) \\ y = \dfrac{x}{\alpha_t (x-1)^{1.7} + x} & (x > 1) \\ x = \varepsilon / \varepsilon_t, \ \ y = \sigma / f_t \end{cases} \tag{2}$$

The compressive stress-strain curve of steel fiber reinforced concrete can be used in Guo Zhenhai model [5].

$$\alpha_d = \left(1.4 + 0.012 f_{fc}^{\ 1.48}\right)\left(1 - 0.8\lambda_f^{\ 0.295}\right) \tag{3}$$

$$\lambda_f = \rho_f \frac{l_f}{d_f} \tag{4}$$

f_{fc} —Compressive strength of steel fiber reinforced concrete， $f_{fc} = f_{ck}$

ρ_f, l_f, d_f —Volume fraction, length, diameter of steel fiber

The tensile curve of steel fiber reinforced concrete is expressed:

$$\begin{cases} y = \alpha_a x + (3 - 2\alpha_a)x^2 + (\alpha_a - 2)x^3 & (0 \le x \le 1) \\ y = \dfrac{x}{\alpha_d (x-1)^{1.7} + x} & (x > 1) \\ x = \varepsilon / \varepsilon_t, \ \ y = \sigma / f_t \end{cases} \tag{5}$$

$$\alpha_a = 1.4\frac{f_t \varepsilon_{ft}}{\varepsilon_t f_{ft}} \quad (6)$$

$$\alpha_d = 0.418e^{0.632 f_t} - 0.446e^{0.826\lambda_f} \quad (7)$$

$$\varepsilon_{ft} = \varepsilon_t + 0.96\lambda_f \times 10^{-4} \quad (8)$$

$$f_{ft} = f_t(1 + \alpha_t \lambda_f) \quad (9)$$

f_{ft}—Tensile strength of steel fiber reinforced concrete;

CONCRETE MATERIAL PARAMETERS

IPLAC yield stress inelastic strain relationship is shown in Figure 1. The damage factor inelastic strain relationship of IPLAC is shown in Figure 2.

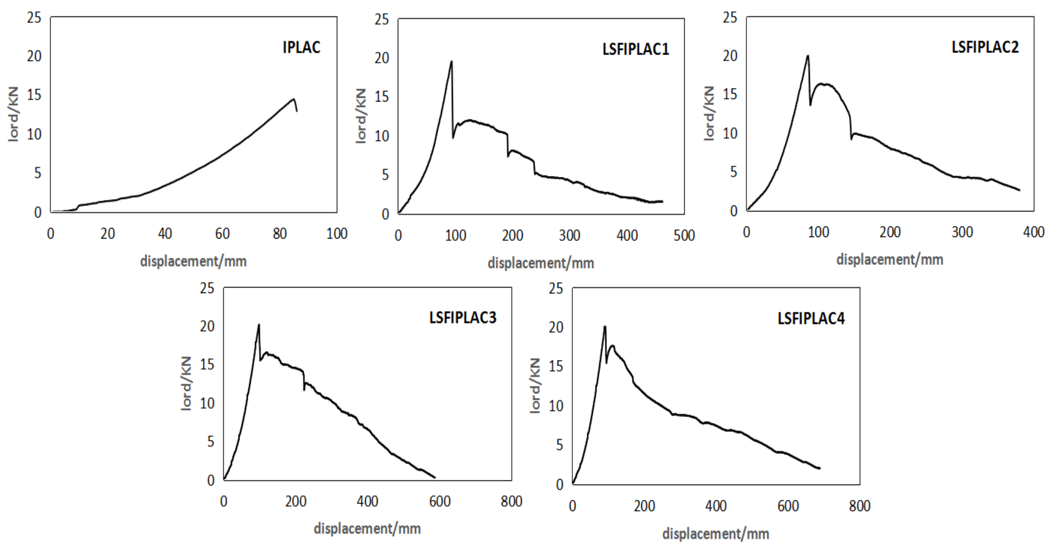
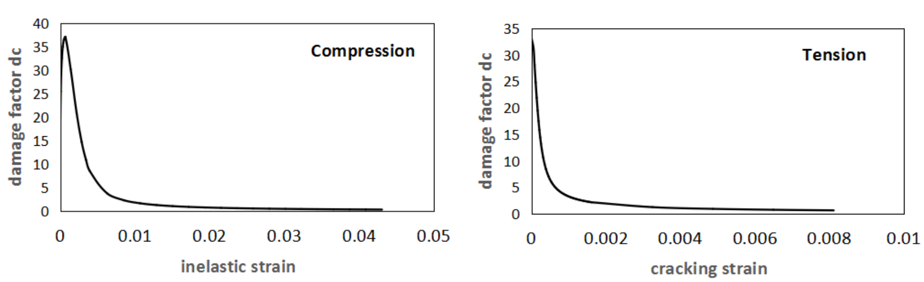


Figure 1. Yield stress and inelastic strain relationship.



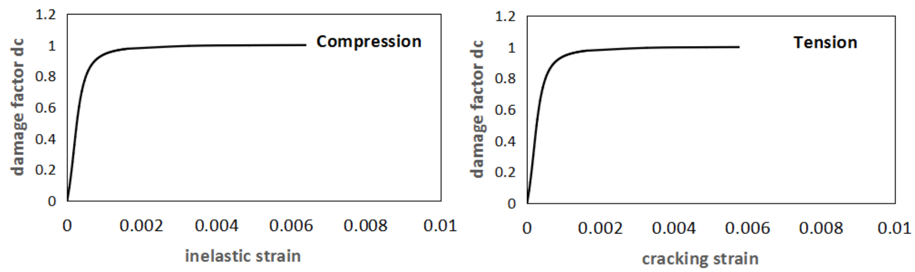


Figure 2. Damage factor inelastic strain relationship.

The material parameters of LSFIPLAC middle layer steel fiber layer adopt the stress-strain relationship of steel fiber reinforced concrete, and the formula is the same with that of IPLAC.

FINITE ELEMENT SIMULATION

Finite element model of specimen are shown in Figure 3.

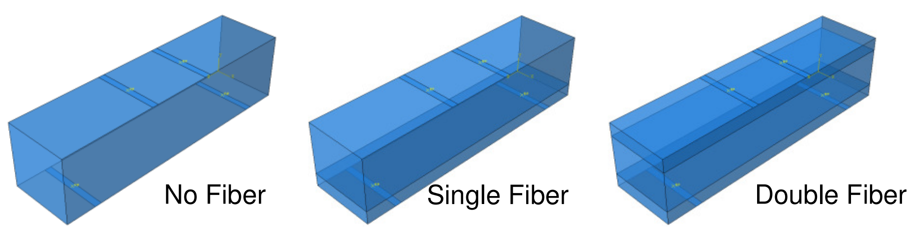


Figure 3. Finite element model.

The ultimate load of finite element simulation is shown in table V. It can be seen that the results of finite element simulation are in good agreement with the test results.

TABLE V. FINITE ELEMENT RESULTS AND TEST RESULTS.

Specimen number	Ultimate load of Finite element simulation P_1/kN	Ultimate load of test P_2/kN	P_1/P_2
IPLAC	13.48	14.37	0.938
LSFIPLAC 1	18.13	19.46	0.932
LSFIPLAC 2	20.05	19.90	1.008
LSFIPLAC 3	21.17	20.12	1.052
LSFIPLAC 4	20.08	20.00	1.004

CONCLUSIONS

Layered steel fiber structure can effectively improve the flexural strength and toughness of inorganic polymer lightweight aggregate concrete. The flexural tensile strength of LSFIPLAC with steel fiber volume ratio of 0.9%, 1.2% and 1.5% increased by 35.44%, 38.52% and 40.03% respectively. The flexural tensile strength of double deck steel fiber increased by 39.24%. The results of finite element simulation are in good agreement with the test results.

REFERENCES

1. Xiaochun Fan, Mingzhong Zhang. “Experimental study on flexural behaviour of inorganic polymer concrete beams reinforced with basalt rebar”. Compos. Eng. 2016, 93: 174-183.
2. Tao Wang. “Research on the layer steel fiber reinforced high strength lightweight aggregate Concrete”, China Railway, 2010, 11:48-50. In Chinese.
3. Xiaochun Fan, Yu Yu, Wenjie Pan, etc. “Research on composite pavement design of layered steel fiber reinforced concrete”, Concrete, 2015, 310(8):146-152. In Chinese.
4. Lingling Fan. Testing study on the toughness of steel fiber reinforced concrete. Hebei University of Technology, 2002. In Chinese.
5. Zhenhai Guo, Strength and constitutive relation of concrete. Beijing: China Building Industry Press, 2004. In Chinese.
6. Jing Zhang, Qingyang Wang, Shouying Hu, etc. “Parameter verification of ABAQUS concrete damage plasticity model”. Building structure, 2008, 08:127-130. In Chinese.