

# Research on Full Stress-strain Curve of Ecological Porous Concrete

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**Abstract:** Through the uniaxial compression test of the porosity between 20% and 30% and the water-cement ratio at 0.25-0.3, 0.3-0.35, the average value of the characteristic points of stress-strain curve of ecological porous concrete with 16-19mm, 19-26.5mm particle size aggregate was obtained, and the curve of stress-strain curve of ecological porous concrete was fitted by ORIGIN mathematical statistical analysis software. The falling curve of ecological porous concrete is inferred virtually, and the full stress-strain curve suitable for ecological porous concrete with different water-cement ratio, strength grade and aggregate particle size is established.

**Keywords:** Ecological Porous Concrete; Stress-strain Curve; Strength; Aggregate Particle Size; Water-cement Ratio.

## 1. Introduction

Ecological porous concrete (Ecological Porous Concrete, EPC) is a kind of environmentally friendly concrete material with large internal pores, which can meet the use function, environmental protection, planting, drainage and noise reduction.

The stress-strain relationship of ecological porous concrete under the uniaxial compression state can well reflect the damage process and deformation characteristics of each stress stage. Due to the complexity of the EPC structure, deformation and damage particularity, the damage mechanism of ecological porous concrete research remains to be strengthened, ordinary concrete and other kinds of concrete stress-strain curve, has a lot of research at home and

abroad, but the ecological porous concrete stress-strain curve research is not much. In order to better promote the ecological porous concrete, it is of great significance to study the stress-strain relationship of EPC.

## 2. Test Profile

The stress-strain curve relationship of ecological porous concrete with water cement ratio within 0.25-0.35 range, porosity between 20% -30%, aggregate particle size of 16-19mm, 19-26.5mm, and concrete strength grade within C5-C10 groups, each water cement ratio interval with 3 water cement ratio, 6 kinds of aggregate particle sizes, 12 groups, each group with 150mm×150mm×300mm specimens. The mix ratio of ecological porous concrete in each group is shown in Table 1.

Table 1. Mix ratio of each group

Experimental group	Aggregate type	Aggregate size (mm)	The amount of aggregate (kg/m <sup>3</sup> )	Porosity (%)	Cement (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	water cement ratio
A	breakstone	19-26.5	1531.8	27.8	284.4-296.3	88.89-100.74	0.3-0.35
B		16-19	1546.6	25.5	314.1-325.9	82.96-94.81	0.25-0.3
C		16-19	1546.6	26.2	302.2-314.1	94.81-106.67	0.3-0.35
D		19-26.5	1531.8	27.3	296.3-308.1	77.04-88.89	0.25-0.3

The test adopts P. O42.5R ordinary Portland cement produced by Nanfang Cement. the coarse aggregate is gravel for construction, reaching grade one class, the water is tapping water, the specimen size is 150mm×150mm×300mm, and the standard maintenance takes 28d.

The stress-strain curve test is operated in conjunction with the pressure tester and the concrete elastic modulus meter. The concrete elastic modulus meter used in the test is shown in Figure 1. The upper and lower rings of the instrument are firmly locked on the specimen through four fixed screws, and the center distance between the two rings is strictly controlled at 150mm. The arc tooth support foot of the fixed screw can ensure the stable connection between the sleeve ring and the specimen. During the test, the pressure test machine and the elastic modulmeter were monitored simultaneously during manual reading. The key characteristic values of the specimen

during the applied load are accurately recorded.



Fig 1. Ecological porous concrete elastic modulus meter

### 3. Test Results and Analysis

#### 3.1. Disstruction Process and Morphology

According to the destruction pattern of ecological porous concrete prisms, its compression damage can be summarized into four stages:

1. Crack stability stage: when the load increases to 40%, ecological porous concrete internal micro cracks and micro holes began to appear and stable, due to the aggregate and cement slurry joint weakest, the specimen internal damage in the main opening pore edge of the cemented material or aggregate and cementing material weak interface transition area. These initial microcracks and microholes will first cause stress concentration at these weak links, leading to material destruction.

2. Crack increase stage: when the load increases to 75%, the cracks keep increasing, and the materials in each area gradually destroy and constantly generate small cracks. In ecological porous concrete, because the connection between the aggregate and the cement slurry is weak, the interface transition zone between the aggregate and the cement slurry will become the main area of stress concentration. These areas first fail when they are stressed, and then gradually expand to the rest of the specimen.

3. Crack connectivity stage: when the load increases to

85%, small cracks gradually converge, the damage area will expand, and the cracks increase until connected.

4. Crack penetration stage: when the load increases to 100%, the connected cracks keep expanding, gradually forming macroscopic cracks, and eventually leading to the complete destruction of the specimen.

See Figure 2 for the destruction process diagram of the specimen:



Fig 2. Prismatic destruction process

#### 3.2. Test Result of Stress-strain Curve Rising Segment of EPC

The average value of the characteristic points of the stress-strain curve is shown in Table 2. The fitted equations are shown in Table 3.

Table 2. Characteristic point test results of the stress-strain curve diagram of the test specimens

The sample group		A		B		C		D	
parameter		$\varepsilon$	$\sigma/\text{MPa}$	$\varepsilon$	$\sigma/\text{MPa}$	$\varepsilon$	$\sigma/\text{MPa}$	$\varepsilon$	$\sigma/\text{MPa}$
falling-rising tone rise section	0	0	0	0	0	0	0	0	0
	0.4	$0.25 \times 10^{-3}$	3.3	$0.27 \times 10^{-3}$	4.68	$0.24 \times 10^{-3}$	4.2	$0.35 \times 10^{-3}$	4.8
	0.75	$0.53 \times 10^{-3}$	6.23	$0.6 \times 10^{-3}$	8.88	$0.52 \times 10^{-3}$	8.2	$0.6 \times 10^{-3}$	7.4
	0.85	$0.76 \times 10^{-3}$	7.06	$0.76 \times 10^{-3}$	10	$0.6 \times 10^{-3}$	8.83	$0.7 \times 10^{-3}$	8.1
	0.95	$0.92 \times 10^{-3}$	7.89	$1.05 \times 10^{-3}$	11.25	$0.8 \times 10^{-3}$	9.9	$0.81 \times 10^{-3}$	8.8
	1	$1.1 \times 10^{-3}$	8.3	$1.4 \times 10^{-3}$	11.83	$1.03 \times 10^{-3}$	10.37	$0.95 \times 10^{-3}$	9.1
strength grade		C5		C10		C10		C5	

Table 3. Fitting equation and correlation coefficient of test stress-strain curve

The sample group	Nonlinear fitting of the equation expression	correlation coefficient	n
A	$y = -9.6 \times e^{\left(\frac{-x}{0.55}\right)} + 9.6$	0.995	15
B	$y = -13.1 \times e^{\left(\frac{-x}{0.54}\right)} + 13.1$	0.995	15
C	$y = -12.05 \times e^{\left(\frac{-x}{0.48}\right)} + 12.05$	0.995	15
D	$y = -12.23 \times e^{\left(\frac{-x}{0.66}\right)} + 12.23$	0.995	15

Among them, the abscissa x: the strain of the ecological porous concrete  $\varepsilon$ ,  $10^{-3}$ ;

vertical ordinate y: stress of ecological porous concrete  $\sigma$ , MPa.

#### 3.3. The EPC Stress-strain Curve Descending Segment

Based on the limitation of test conditions, at the same time considering the ecological porous concrete stiffness and strength is not enough, the destruction of the brittleness damage, cannot by ordinary pressure tester stress-strain curve

down, so by finding the relevant information, select strength of specimens, virtual analysis of ecological porous concrete falling curve. After comparison, the following three concrete stress-strain drop section equations are selected to predict the stress-strain drop curve section of ecological porous concrete ( $\sigma/\sigma_{pr}$  for the ordinate  $y$ ,  $\varepsilon/\varepsilon_{pr}$  for transverse coordinates  $x$ ):

$$y = \frac{x}{7.296(x-1)^2 + x} \tag{1}$$

$$y = \frac{x}{5.327(x-1)^2 + x} \tag{2}$$

$$y = \frac{x}{2.35x^2 - 2.76x + 1.41} \tag{3}$$

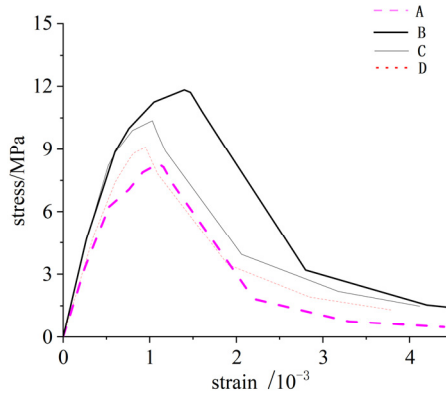
**Table 4.** Fitting equation and characteristic point values of the descending segment

descending branch	$1.05\varepsilon_{pr}$	$1.15\varepsilon_{pr}$	$2\varepsilon_{pr}$	$3\varepsilon_{pr}$	$4\varepsilon_{pr}$
$y = \frac{x}{7.296(x-1)^2 + x}$	0.98	0.88	0.22	0.09	0.057
$y = \frac{x}{5.327(x-1)^2 + x}$	0.99	0.91	0.27	0.13	0.08
$y = \frac{x}{2.35x^2 - 2.76x + 1.41}$	0.95	0.86	0.38	0.21	0.143

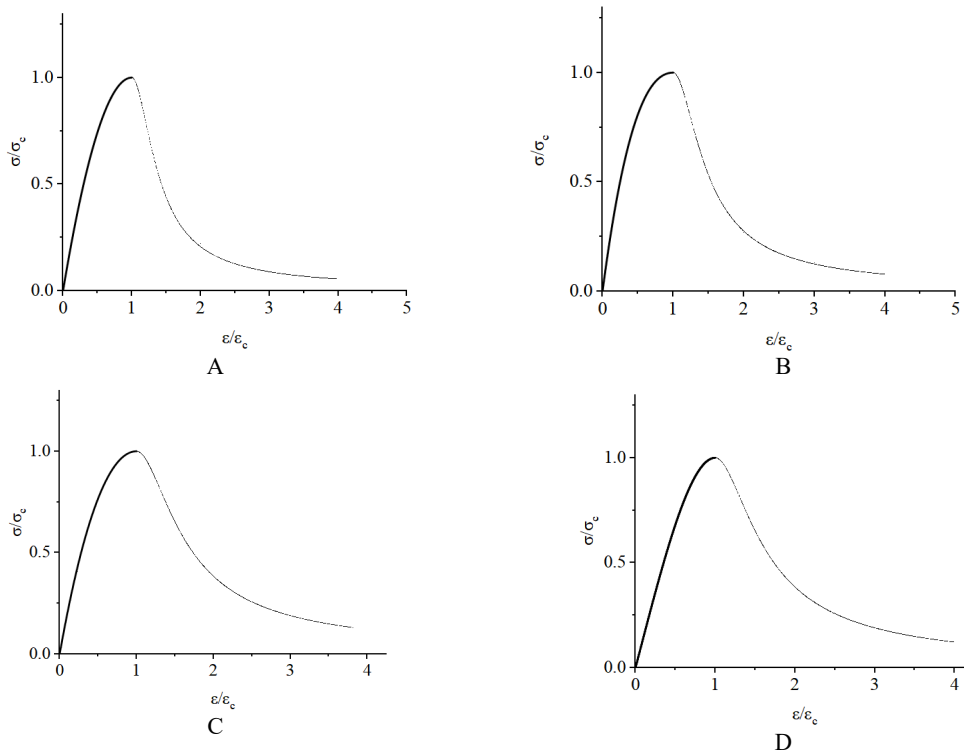
Note: Formula 1 and 2 are all from document [3] and Formula 3 are from document [4]. Through the comparative analysis of EPC drop section, formula 1 is selected for group A, formula 2 for Group B, and Group C and D are selected formula 3 for simulation.

### 3.4. Full Stress-strain Curve of Ecological Porous Concrete

After calculating the EPC stress-strain drop segment from the constitutive model proposed in literature [3][4], the full stress-strain curve is shown in Figure 3 below:



**Fig 3.** Full stress-strain curve of ecological porous concrete



**Fig 4.** Stress-strain curve

Figure 3 shows the full EPC stress-strain curve with different water cement ratio interval and different strength grades. With the increase of water cement ratio and strength grade, both peak stress and peak strain increase; the peak stress and peak strain decrease with the increase of aggregate particle size; and the decreasing section of the full stress-strain curve becomes more steeper with the increase of concrete strength grade, and some have steps but the overall shape without not change.

The full stress-strain curve of ecological porous concrete fitted by Professor Zhenhai's model is shown in Figure 4.

#### **4. Conclusion**

Through the uniaxial compression test of the porosity between 20% and 30% and the water-cement ratio at 0.25-0.3, 0.3-0.35, the average value of the stress-strain curve of ecological porous concrete mixed with 16-19mm, 19-26.5mm particle size aggregate was obtained, and the stress-strain

curve was fitted by ORIGIN mathematical statistical analysis software. The falling curve of ecological porous concrete is inferred virtually, and the full stress-strain curve suitable for ecological porous concrete with different water-cement ratio, strength grade and aggregate particle size is established.

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