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Foam Concrete Precast Elements in Composite Concrete-GFRP Plate Girders

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Abstract: This paper is focused on using foam concrete as structural element in polymer-concrete composite plate girders. Trial mixes of foam concrete and different proportions of foam agent were considered to obtain the suitable mix that can be used as structural element in composite girders system. Details of the experimental investigations on foam concrete precast slabs and polymer-concrete composite plate girders subject to shear action are presented in this paper. Composite plate girders have been tested to failure in order to study the ultimate load behavior. Effects as positions of slab under load and carbon fibers as external confinement have been considered.

Keywords: Foam concrete, composite plate girders, polymer girder, ultimate shear strength, precast concrete.

1. Introduction

Foam concrete has characteristic of light weight concrete and applied recently as a composite bridge of concrete slabs and GFRP girders. Foam concrete can be produce as small units precast or cast in situ concrete due to easy to be placed and finished also foam concrete is free flowing pumpable and easy handling and fabrications [2].
The use of Glass Fiber Reinforced Polymer (GFRP) has gain a wider space in civil engineering construction as load-bearing component especially in foot bridge construction, due to the considerable properties as high specific strength, high modulus of elasticity and good corrosion resistance. Materials with these properties can provide a high level of mechanical and structural and mechanical performance.[3,4,5,6].
GFRP recently used as composite structural component. Such composite has many structural characterizations as, low density, high durability, high strength and good stiffness to weight ratio. Ease of installation make it a suitable structural material and can perfectly be in place of traditional common materials as concrete and steel.[7]. The current paper is concerned with precast foam concrete/ GFRP composite plate girders. Experimental tests have been used to investigate the elastic and ultimate load behavior. Results are presented to show the effects of foam concrete precast slabs, carbon fiber as reinforcement of concrete slabs and position of slabs under load.

2. Experimental Investigation

Tests on four precast foam concrete slabs/ glass fiber reinforced polymer I-girders (GFRP) composite plate girders (CPG1 to CPG4) and a precast slab on prism concrete beam (CCG) subjected to shear loading have been tested. The dimensions of polymer girders in (CPG1 to CPG4) are kept the same size with b_f=80mm, d=100 mm, t_f=8mm and t_w=10 mm. Cross section of tests girders shown in Figure 1.

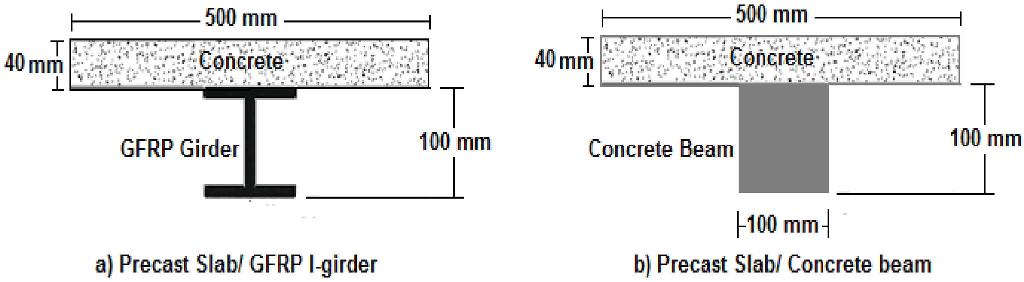

Figure 1. Cross-sectional dimensions of tested girders

In all specimens, CPG1 to CPG4 and CCG, foamed concrete (FC) with 1% of foam agent were be used in slabs. Load applied on the systems at the center of the span as shown in Figure 2 and deflection is measured at the same point (V_o).

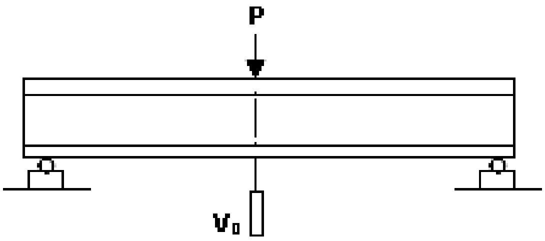

Figure 2. Loading details of tested girders

Carbon Fiber sheets (CFS) used to strengthen the precast slabs in specimens CPG3 and CPG4 as listed in Table 1. Specimens, CPG1, CPG3, and CCG are tested when slab under compression (C) and others are tested under tension (T). Types of tested girders are shown in Figure 3.

Table 1: Details of the specimens

Specimen	Typeof Girder	Typeof Slab	ExternalReinforcement	Slab Position
CPG1	GFRP	FC	-----	C
CPG2	GFRP	FC	-----	T
CPG3	GFRP	FC	CFS	C
CPG4	GFRP	FC	CFS	T
CCG	FC	FC	-----	C

a) CPG1and CPG2 (slab without reinforcement)

b) CPG3 (slab with CFS reinforcement)

c) CPG4 (slab under tension with CFS reinforcement)

d) CCG (slab under compression without reinforcement on concrete beam)

Figure 3. Tested girders

3. Foam Concrete

Trial mix method was used to performed light weight foamed concrete (FC) mixture. Optimum w/c that produced a lower density and desirable structural strength was depended from trial mixes. The mix proportions obtained was 1:2.25 by weight, w/c=0.46 accordance to ACI 211 [8].

Foam is used as a portion of mix as 0.6, 0.8, 1.0, 1.2 and 1.5 kg/m^3. The prefoaming method was used to produce light weight foamed concrete. The procedure was:
Weighing sand, cement, water, and foam agent according to mix proportions.

1. Mixing dry materials sand and cement with mechanical drum mixer for 2min.
2. Adding required water to sand and cement and mixing for 5-8 min. to performed base mix.
3. Using drilled mixer foam agent mixed with required water and mixing for 3-5 min. to obtain desired homogenous and workable mix.

Foamed fresh concrete then placed in to cast iron molds 150x150x150 mm cubes, 100x200 mm and 150x300 mm cylinders and 100x100x40 mm prisms to check foamed concrete properties and casting in wood molds 250x500x40 mm slabs and cast iron 100x100x500 mm prisms for composite test. Fresh concrete then was casted in layers; each layer was compacted by using a vibrating table for not more than 5 seconds. After completion placement the specimens were kept covered with polyethylene sheet in the laboratory for about 24 hours, then the samples removed from the mold and immersed in water bath 23±3˚c until test time as shown in Figure 4.

Figure 4.Casting and removed concrete slabs from molds

Foamed concrete were tested to obtain the mechanical properties. The concrete samples in harden state were tested for compressive strength at the ages 7 and 28 days according to BS. 1881: part 116 [9], splitting tensile strength at the age of 28 according to ASTM C496 [10], flexural strength, at the age of 28 days according to ASTM C78 [11] and modulus of elasticity according to ASTM C469 [12]. Results of tests are listed in Table 2. Flowability of fresh foamed concrete samples was checked by flow table test according to ASTM C1437 as shown in Figure 5 [13].

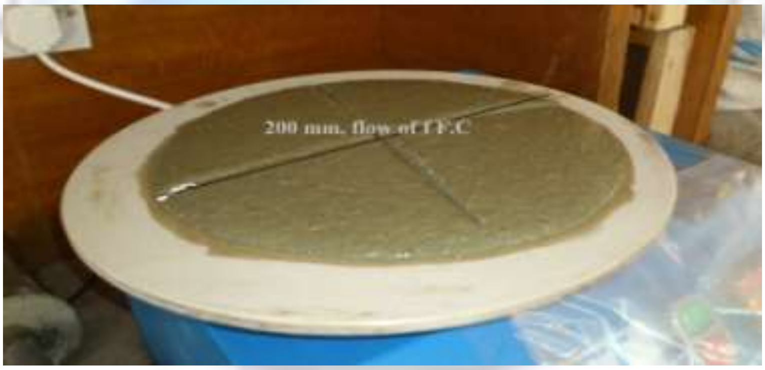

Figure 5. Flow test of foamed concrete

The glass fiber polymer reinforced (GFRP) girders was manufactured locally. Components of polymer are resin, cobalt, hardener, herosin and Potassium Nitrate with portions according to the European standard for Polya Company [14]. These components mixed to produce the polymer that placed in I-shape molds with internal reinforcement of glass fiber nets in order to produce GFRP I-girders. The resultant polymer has properties of Young's Modulus equal to 32.4 kN/mm^2, yield stress of 270 N/mm^2 and Poisson's ratio of 0.3.

Table 2: Mechanical properties of ordinary and foamed concrete

% Foam (kg/m^3)	Density (kg/m^3)	Compressive Strength, f_c' (MPa)		Flexural Strength, σ (MPa)		Splitting Strength (MPa)	Modulus of Elasticity (MPa)
		7 days	28 days	7 days	28 days		
0.6	2100	15.3	22.1	3.3	4.8	3.5	23000
0.8	1990	14.8	21.4	2.8	4.1	3.2	21000
1.0	1890	13.3	18.8	2.6	3.8	2.9	20000
1.2	1870	11.4	16.5	2.3	3.0	2.1	19000
1.5	1850	10.1	14.1	1.6	2.2	1.4	16000

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4. Results and Discussion

The results provided detailed output in terms of displacements, stresses, strains and forces. However, for brevity only the most relevant results are presented herein for discussion. Figures 6 and 7 show the load-vertical deflection plots for the tested girders. Deflection measured at the center of the span is plotted against the corresponding applied load (P). In these figures, results corresponding composite girdersare presented along with that for concrete slab/ beam (CCG) for comparison.

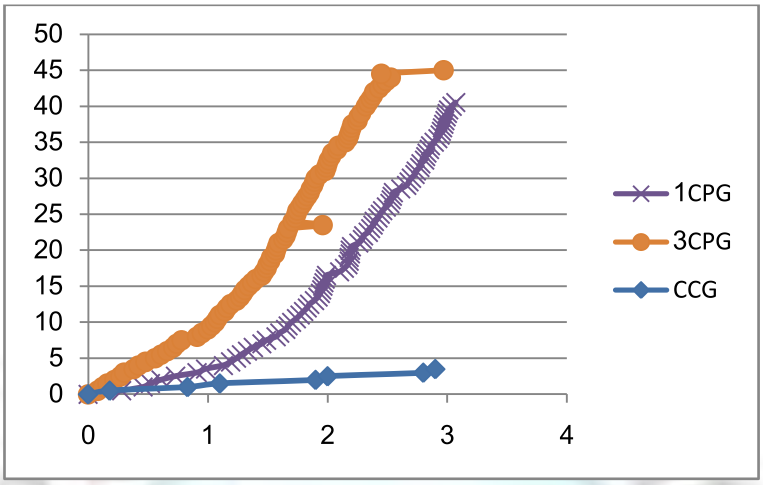

Figure 6. Load-deflection plot for tested girder when slabs under compression

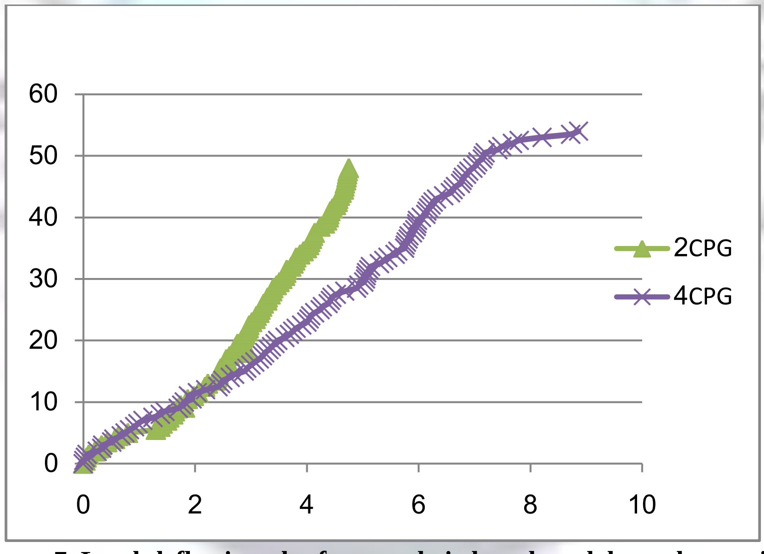

Figure 7. Load-deflection plot for tested girder when slabs under tension

An elastic behavior at the initial stages is observed for all the GFRP girders and it becomes nonlinear soon after reaching the ultimate condition. The behavior of the girders is similar when slabs under compression and enhancement in stiffness and ultimate load-carrying capacity compared to concrete beams can be witnessed in all tested girders. GFRP girders exhibit significant gain in the ultimate load capacity, ranging from 90% to 94% over the corresponding values for concrete beams. The gain should be attributed to the contribution by the presence of concrete slab with GFRP girders and the composite action. Table 3 listed the failure loads and maximum deflections of tested specimens.

Table 3: Failure loads and maximum deflection of tested girders

Specimen	Failure Load (*MPa*)	Maximum Deflection (*mm*)
CPG1	48	4.47
CPG2	40.5	3.07
CPG3	54	8.86
CPG4	45	2.97
CCG	3.5	2.9

After the onset of plastic range the girder continues to carry larger load. Figure 8 shows the state soon after reaching the failure load. The GFRP girder under larger shear appears to have suffered soon after reaching the failure load. As the displacement is increased up to the failure load, the GFRP are subject to larger deformation and load beyond the ultimate condition leads suddenly to collapse of the girder.

a) CPG1 after failure

b) CPG2 after failure

c) CPG3 after failure

d) CPG4 after failure

e) CCG after failure

Figure 8. Tested girders after failure

GFRP girders in tension zone have increased the ultimate load capacity about 16% over the corresponding values for GFRP girders in compression zone for composite girders with light weight foam precast concrete slabs. CFS reinforcement of concrete slabs have increased the ultimate load of composite GFRP girders about 10% and 11% for composite GFRP girders with light weight foam concrete slabs when slab under compression and tension, respectively.

Maximum displacements of GFRP composite girders at failure load have increased in reinforced slabs about 50% when slabs under compression and displacements have increased in reinforced slabs about 3% when slabs under tension.After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

5. Conclusions

The studies presented herein show that the elasto-plastic experimental results are capable of predicting the ultimate load behavior of concrete/ GFRP composite I-girders. Experimental study has been carried out on composite girders with GFRP girders and prism concrete beams with effect of CFS reinforced precast concrete slabs. It is apparent from the results that accounting for composite concrete/ GFRP girders have yield in larger load carrying capacity. The CFS reinforcement on concrete slabs has insignificant effect on load carrying capacity when slab under compression compared to slab under tension. It is obvious from the results that ultimate load of ordinary concrete slabs in composite girders is larger than the corresponding composite girders with foam concrete slabs. Deflection increased in composite girders when slabs under compression compared with the composite girders having slabs under tension.

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