**Engineering And Technology Journal e-ISSN: 2456-3358**
**Volume 03 Issue 07- July 2018, Page No- 451-455**
**DOI:10.31142/etj/v3i7.02, I.F. - 4.449**


# Effect of Adding Glass Fibre Reinforced Concrete Topping on Flexural Behaviour of Hollow Core Slab Units

**Liaqat A. Qureshi[1], Ali Ajwad[2], Babar Ali[3]**

[1,2,3]University of Engineering & Technology, Taxila, Pakistan

**Corresponding Author: Liaqat A. Qureshi[1]**
University of Engineering & Technology, Taxila, Pakistan

**Abstract:** This paper presents an experimental study regarding the effect of using glass fibre reinforced concrete topping on flexural capacity of hollow core precast prestressed slab units. Two glass fibre reinforced concrete (GFRC) toppings of 32 mm and 65 mm thicknesses were used on 200 mm depth hollow core slab units. Cylinder strength of hollow core slab concrete was 45.7 MPa while that of GFRC toppings was designed as 38.6 MPa. Flexural loading was applied to topped and control slabs and effect of addition of topping was studied compared to the control slabs with no topping. Results show that addition of topping can improve the flexural strength of hollow core slabs by 50% with 65 mm topping while around 20% for 32 mm topping. The increase in flexural capacity was found linear with the thickness of topping. It was also observed that flexural strength of concrete topped slabs is almost equal to the capacity of un-topped slabs of similar depth.

**Keywords: Hollow core slab, Precast slab, Flexural capacity, Extra topping, Glass fiber,**

## I. Introduction

Prestressed concrete is defined as “Concrete in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from given external loadings are counteracted to a desired degree.” It further goes on to say, “In reinforced concrete members, the prestress is commonly introduced by tensioning the steel reinforcement” [1]. Prestressing is thus a method that improves the properties of a structure by adding and prestressing high performance steel. Prestressing means the intentional creation of permanent stresses in a structure or assembly, for the purpose of improving its behavior and strength under various service conditions [2].

When the slabs are cast, the surface of the slabs is usually not finished level. During the time of its onsite installation, the surface is leveled with a cast in-situ screed or concrete topping. As the thickness of the topping is too small, its relative effect on the flexural capacity of the slab is normally neglected. Moreover, unpredictability prevails over the bond behavior between the slab and the concrete topping. Precast prestressed hollow core slabs are widely used in European countries but their use in Pakistan is limited mainly because of the limited availability of the units locally. In addition to this, the slabs are only produced in two standard thicknesses i.e., 200 mm and 265 mm which offer very little flexibility in design and installation of slabs. There might be a scenario when the loading is in such a way that 200 mm comes out to be not satisfactory and the requirement of the slab loading is than 265 mm depth. At that time this sort of topping criteria might come in handy. For this to be fruitful, the bond behavior between the old and fresh concrete needs to be adequate. That’s why the use of bonding agent might be introduced, if the simple bond between old and fresh concrete is inadequate.

Considerable amount of research work has been done on prestressed hollow core slabs with topping. Rahman et al., did research on slabs of different depths and came out with a conclusion that the failure mode of hollow-core slabs changed from pure flexure mode to flexure-shear mode for slabs with depth greater than 200 mm. Flexural behavior of hollow core slab units with concrete topping was studied by Dowel & Smith, who clarified that the topping performed satisfactorily in flexure and there was no shear slip found at the interface during the application of load [4]. Ueda & Stitmannaithum investigated the shear capacity of hollow core slab units with concrete toppings. His main focus was on thickness of concrete topping, tensile reinforcement, prestressing force and span to effective depth ratio [5]. Girhammer & Pajari also studied the effect of concrete topping on the shear capacity of hollow core slab units. They found the bond at the interface to be adequate and increase in shear capacity was observed to be around 35 percent, although no work on the flexural strength of the hollow core slab unit was done by them [6].

Glass Fiber Reinforced Concrete (GFRC) is a type of fiber reinforced concrete used in some principal tensile load carrying members. GFRC is an important cement based composite that uses fine sand, cement, water, admixtures and alkali-resistant (AR) glass fibers. The glass fibers are very fine chopped fibers of glass about 10 mm to 30 mm in length and 12 to 15 micrometers in diameter. The polymer and concrete matrix serves to bind the fibers together and transfer loads from one fiber to another via shear stresses through the matrix. In order to resist tensile loads, there needs to be an adequate amount of fibers. Often a loading of 5% fiber by weight of cementitious material is used. Glass fiber used in quality GFRC has a higher tensile strength. As a general rule, the higher the fiber content, the higher the strength. A typical mix with 5% glass fiber has a compressive strength of 41 to 55 MPa. Glass fiber reinforced concrete has been tested both by accelerated aging tests in the laboratory and in real life installations. GFRC can be expected to last as long as pre-cast concrete. In many environments, when exposed to salt spray or high moisture, the GFRC performs better due to absence of steel reinforcement to corrode. It is less susceptible to weather erosion and has more freeze thaw resistant than conventional concrete. The use of glass fibers for reinforcement means it cannot rust and thus can be used under salt water and in marine environments. GFRC has 80 to 95% less weight than that of solid concrete. This makes it easier and faster to install and reduces the load on the structures. The lighter weight and stronger material also saves transport costs, allows more design freedom and by using less material, reduces environmental impacts [7].

This research work was planned to look at the effect of adding glass fiber reinforced concrete topping on the flexural strength of hollow core slab units. In order to do so, two topping depths were selected as 32 mm and 65 mm, both on 200 mm thick slabs. SBR latex (Styrene Butadiene) was used as bonding agent to strengthen the bond between topping and hollow core slab units due to unpredictability in bonding behavior between old and fresh concrete. The bonding agent was used with cement slurry in the ratio of 1:1:4. The solution was applied to the surface of the slabs and GFRC was poured on the top while the solution was still wet.

## II. TESTING PROGRAM

### *A. Testing arrangement*

The test specimens consisted of four full-scaled slabs tested under point load applied at their mid-spans. There were two control slabs abbreviated as CONT200 & CONT265 having 200 mm and 265 mm depth respectively. Out of the other two 200 mm original depth slabs, one was topped with 32 mm and the other with 65 mm thick toppings. The control slab of 200 mm depth i.e., CONT200 was tested to study the effect of different additional topping depths on its flexural strength. The control slab with 265 mm depth i.e., CONT265, was tested to compare its flexural behavior with 65 mm topped slab with total depth of 265 mm. The surfaces of all slabs were roughened before the application of topping with steel brush. Hollow core slabs had a width of 990 mm with five 155 mm dia holes running along their 2400 mm length. Prestressed strands of 10 mm diameter were used and an initial internal tensile stress of 110 MPa was induced in the tendons by prestressing. The area of steel used was 235.65 $mm^2$ in both CONT200 and CONT265. The cross sections of the 200 mm and 265 mm slabs can be seen in Figures 1 and 2 respectively whereas the testing arrangement for the application of load is shown in Figure 3. Table 1 summarizes the detailed description of slab specimens tested in the research program.

**TABLE 1- SLAB DESIGNATIONS**

| Sr. No. | Slab ID | Slab Depth (mm) | Topping Depth (mm) | Topping Type |
|---|---|---|---|---|
| **1** | CONT200 | 200 | - | - |
| **2** | CONT265 | 265 | - | - |
| **3** | GFRC32 | 200 | 32 | GFRC* |
| **4** | GFRC65 | 200 | 65 | GFRC* |

* Glass fiber rein forced concrete (38.6 MPa)

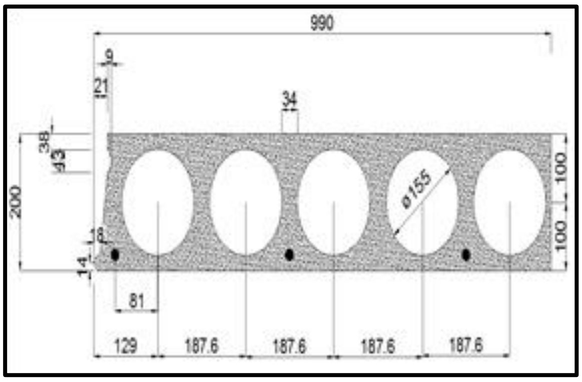


**Figure 1:** Cross section of hollow core slab with 200 mm depth

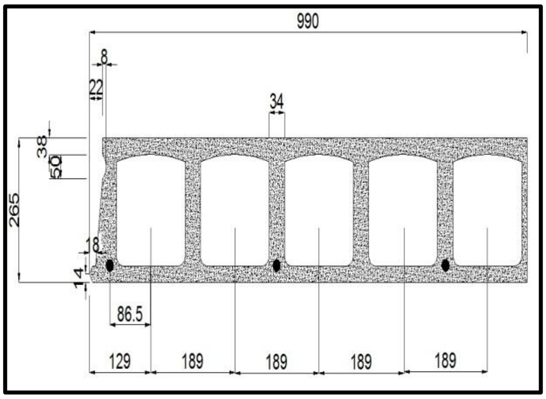


**Figure 1:** Cross section of hollow core slab with 265 mm depth

**Figure 3:** Testing arrangements for slabs in flexural loading

Tests were performed after 28 days of the application of topping. The hollow core prestressed slabs were tested under flexural test conditions of three point loading. A schematic diagram of the flexural testing set up is shown in Figure 4. A load increment of 10 kN was selected until the failure of slabs. Dial gauges were fixed on underside of the slabs right below the point of application of load for the measurement of mid-point deflections. The development of first crack and subsequent cracks appeared up to the failure of slabs, were carefully monitored and respective loads noted.

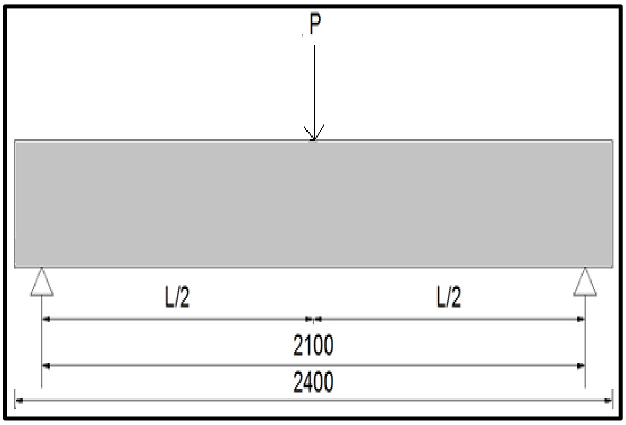


**Figure 2:** Schematic diagram of the test

## III. RESULTS AND DISCUSSION

### *A. Ultimate moment capacity*

Experimental ultimate moments were calculated as a product of failure load noted during testing and its perpendicular distance from the support. Theoretical ultimate moment capacity was also calculated by the formula given by Elliott [8]:

$$M_u = f_{pb} A_{ps} (d - d_n) \qquad (1)$$

Where

$M_u$ = ultimate moment capacity (kNm);

$f_{pb}$=design stress in tendons = $0.87f_{pu}$ = 1540Nmm$^2$;

$A_{ps}$ =Area of prestressing steel tendons

= 235.65mm$^2$;

d = $y_t$(distance to centroid) + e(eccentricity) (mm);

$d_n$ =depth of compression zone

= $2.47\{[A_{ps}f_{pu}/(bdf_{cu})][f_{pb}/f_{pu}]d\}$

= 18mm

Figure 5 shows a comparison between theoretical and experimental ultimate moment capacities for the slabs with ultimate load taken by them. Theoretical values for the ultimate moment capacity were calculated by using equation 1.

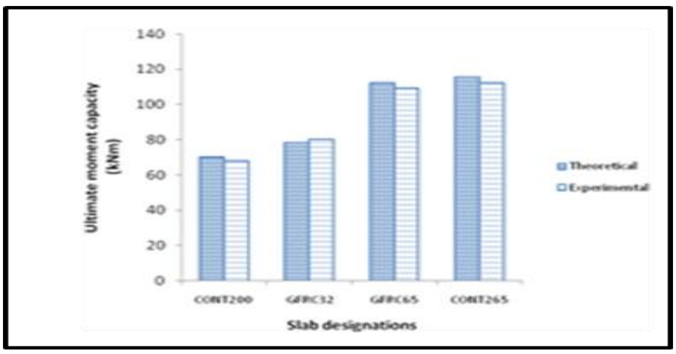


**Figure 3:** Ultimate moments for slabs

Figure 5 shows that there is 6% increase in ultimate moment capacity by applying 32 mm thick GFRC layer and about 50% by applying 65 mm layer. Comparison of ultimate moment capacity of GFRC65 with that of CONT65 exhibits that the 265 mm thick originally cast control slab behaved similarly to a 265 mm thick topped slab. Experimental results of ultimate load capacity stood well in agreement with the corresponding calculated values.

### *B. Deflections*

For calculating the theoretical values of deflection, the equation derived by Bhatt [9] was used. The topping was considered as a part of the slab when calculating moment of inertia. This equation was only applicable up to the point where first cracks appeared and is given as under:

$$a_e = \left(\frac{L^2}{E_{c,t} I}\right) \sum kM \qquad (3)$$

Where,

L = Span of slab = 2400 mm;

M =Maximum bending-moment in the span (N-mm);

K=Factor that depends on the shape of the bending-moment diagram;

I =Moment of inertia (mm$^4$);

$E_{c,t}$= Modulus of elasticity at an age which can be derived from the following equations:

$$E_{c,20} = 20 + 0.2 f_{cu,28}$$

$$E_{c,t} = E_{c,20}\left(0.4 + \frac{0.6 f_{cu,t}}{f_{cu,28}}\right) where \quad t > 3days$$

For calculating camber due to prestressing, the following equation was used:

$$a_e = L^2 \Big/ (E_{c,3} I)(1/8)(-\eta_t P_{0p} e_p) \qquad (4)$$

where

L = Span of slab = 2100 mm;

K = Factor that depends on the shape of the bending moment diagram;

I = Moment of inertia (mm$^4$);

$E_{c,3}$= Modulus of elasticity at an age of 3 days which can be derived from the following equations:

$$E_{c,20} = 20 + 0.2 f_{cu,28}$$

$$E_{c,t} = E_{c,20}\left(0.4 + \frac{0.6 f_{cu,t}}{f_{cu,28}}\right) where \quad t > 3days$$

$-\eta_t$= Constant=-0.89;

$P_{op}$ =Initial prestressing force=110N/mm$^2$;

$e_p$=Eccentricity of tendons = 68.4 mm

By substituting all the values, camber can be calculated as

$$a_e = L^2 \Big/ (E_{c,3} I)(1/8)(-\eta_t P_{0p} e_p)$$

$$a_e = 2100^2 \Big/ (19 \times 10^3 \times 659.01 \times 10^6)(1/8)(-0.89 \times 235.65 \times 10^3 \times 68.4)$$

$$a_e = -0.64mm$$

Figures 6 to 9 give comparison between experimental and theoretical values of net deflection. In these Figures, the theoretical values were obtained from equation 3 and 4 whereas experimental values were taken from the dial gauges during testing. Net deflection means experimental/theoretical deflection minus camber due to prestressing.

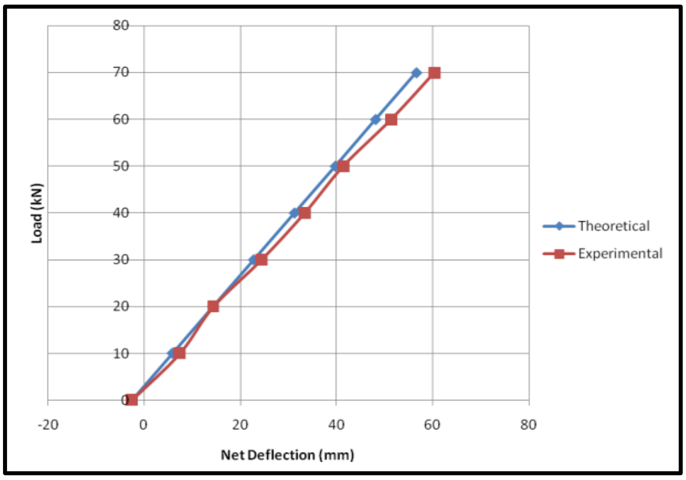


**Figure 4:** Load-deflection curves for CONT200 up to cracking

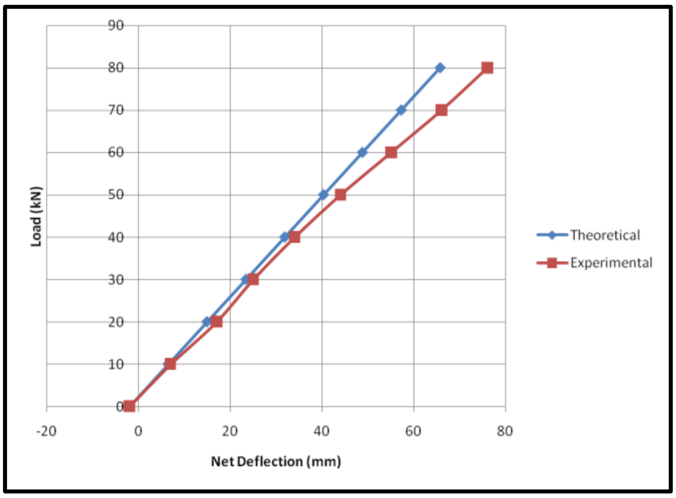


**Figure 5:** Load-deflection curves for GFRC32 up to cracking

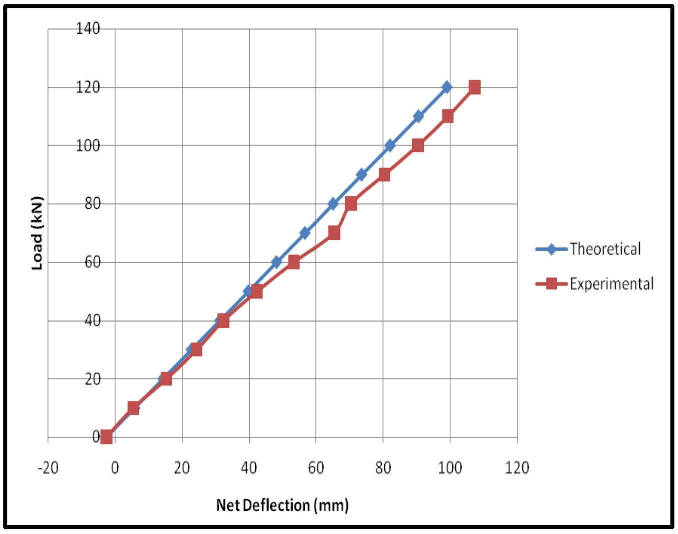


**Figure 6:** Load-deflection curves for CONT265 up to cracking

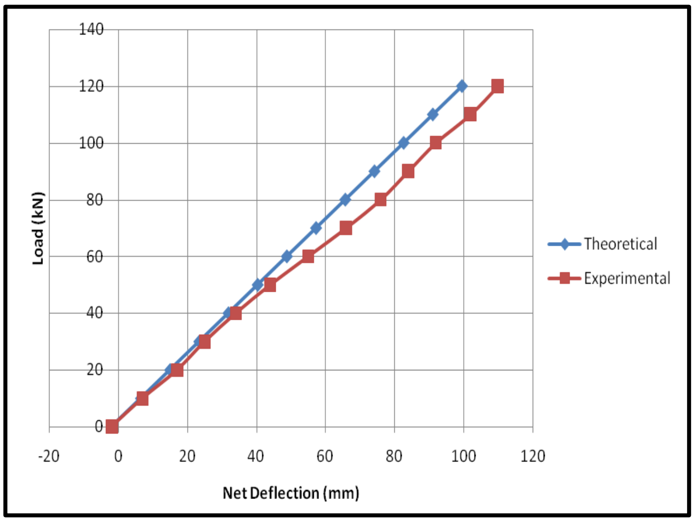


**Figure 7:** Load-deflection curves for GFRC65 up to cracking

It can be seen from Figures 6 to 9 that the experimental and theoretical values of deflections for all slabs were almost similar until the appearance of the first crack, although for the GFRC topped up slabs, the deflection was slightly more as compared to the control slabs. This was due to the fact that glass fibre reinforced concrete shows better elastic behavior as compared to normal concrete.

### C. Effect of Topping Depth on Flexural Capacity

Figure 10 shows the load-midspan deflection curves for 200 mm slab without topping and with toppings. It is evident from the results given in Figure that toppings improved flexural capacity of the slab units up to 55 percent with the increase in topping depth. When concrete failed and the load transferred to the prestressed strands, deflection increased linearly with the increase in load. All slabs failed within 15 kN increase in load after the first crack appeared. Also in all slabs, vertical cracks were noticed initiating from the bottom of slabs directly under the point of application of loading and propagating towards the top. It shows that all slabs failed under pure flexure.

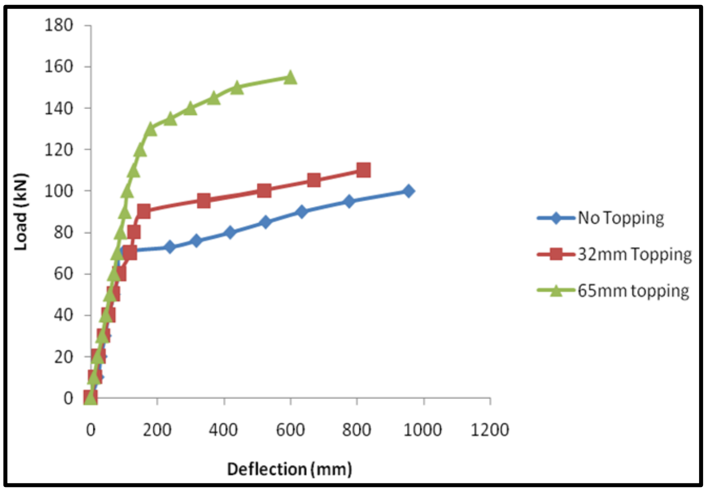


**Figure 8:** Load-deflection curves for GFRC topping

Figure 11 shows a comparison of first cracking, yielding point and breaking point loads for all slabs. It can also be noticed from the graphs that increase in flexural strength is linear with the increase in topping depth and increase in flexural strength is 6 percent in the case of the 32mm topping and 50 percent in the case of the 65 mm topping as compared to the 200 mm depth slab with no topping. Also the 200 mm depth slab with 65 mm topping (GFRC65) achieved a flexural strength almost equal to CONT265, with the same total depth.

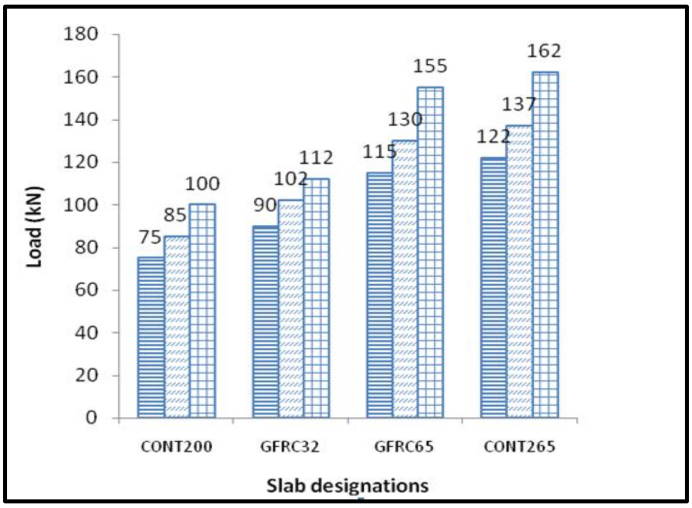


**Figure 9:** Critical loads for all slabs tested

Figure 12 shows a comparison of load-deflection values for both slabs with the same total depth. It is clear from Figure 12 that the flexural capacity for the two slabs was almost the same i.e. 115 kN for GFRC65 and 122 kN for CONT265. The corresponding displacements were 140 mm for GFRC65 and 103 mm for CONT265. It means that whether a precast slab of 265 mm depth is used or a 200 mm depth slab with 65 mm topping, the total load they would carry will be the same. It is also proved that the topping interacts monolithically with the slab and no shear slip occurred during the application of load, provided proper preparation of the slab surface is done at their interface by using a bonding agent.

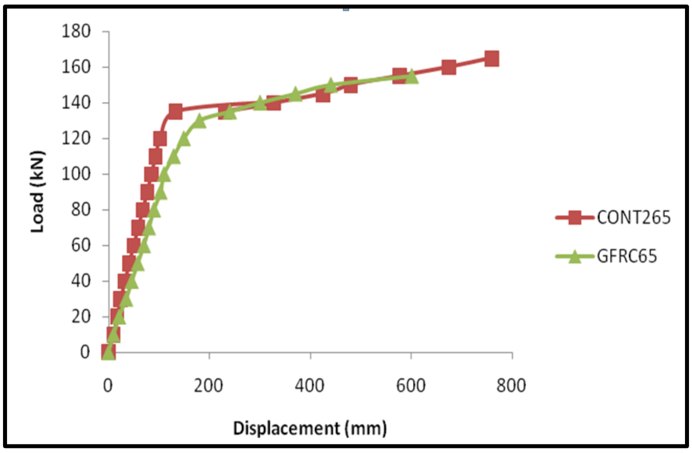


**Figure 10:** Load-deflection curves for CONT265 and GFRC65

## CONCLUSIONS

After detailed experimental study regarding the effect of using glass fibre reinforced concrete topping on flexural capacity of hollow core precast prestressed slab units and comparing it with theoretical study, the following conclusions were made;

1) High strength concrete topping can be used to increase the flexural capacity of hollow core slab units. It is seen that up to 50 percent increase in flexural capacity can be achieved with 65 mm topping and around 6 percent with 32 mm topping.
2) The flexural capacity of the concrete topped slabs was found equal to the capacity of the control slab of similar depth without topping.
3) Experimental and theoretical moment capacities fitted well with each other.
4) Experimental midspan deflection versus load curves coincided well with the corresponding theoretical curves which verify outcomes of previous research.
5) The increase in flexural capacity of the hollow core slab units was found linear with the increase in topping depth. When the topping depth was doubled from 32 mm to 65 mm, the load bearing capacity was also doubled.

## REFERENCES


1. British Standards Institution., Eurocode, "Basis of Structural Design". BSI, london, BS EN, 1990.
2. Elliott, K. "Precast Concrete Structures". Ist Edition, Oxford: Antony Rowe Ltd, 1-104. 2002.
3. Rahman, M. K., Baluch, M. H., Said, M. K., & Shazali, M. A. "Flexural and Shear Strength of Prestressed Precast Hollow-Core Slabs". Arabian Journal for Science and Engineering, 37 (2), 443-455, 2012.
4. Dowell R. K & Smith J.W. "Structural Tests of Precast, Prestressed Concrete Deck Panels for California Freeway Bridges". PCI J, 51(2), 76–87, 2006.
5. Ueda, T. & Stitmannaithum, B. "Shear Strength of Precast Prestressed Hollow Core Slabs with Concrete Topping". ACI Structural Journal, 88(4), 402–10, 1991.
6. Girhammar, U. & Matti Pajari. "Tests and Analysis on Shear Strength of Composite Slabs of Hollow Core Units and Concrete Topping".Construction and Building Materials, 22 (1), 1708–1722, 2008.
7. Kumar, V. S., Thomas, B.S. & Christopher, A. "An Experimental Study on the Properties of Glass Fibre Reinforced Geopolymer Concrete". International Journal of Engineering Research and Applications, 2 (6), 722-726, 2012.
8. Elliott, K. "Precast Concrete Structures". Eq. 4.26, Ist Edition, Oxford: Antony Rowe Ltd, 2002.
9. Bhatt, p. "Reinforced Concrete: Design Theory and Examples". 3rd ed, London, Taylor & Francis, Chapter 16, 559-583, 2006.