FLEXURAL CAPACITY OF RC BEAMS WITH EXTERNALLY SHEAR STRENGTHENING USING GFRPSHEET

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Abstract- Combination of several materials to create a structural system has led to new kinds of innovative infrastructure applications. The addition of Glass Fiber Reinforced Polymer(GFRP) laminated bonded to the tension face of concrete member is an attractive solution to the rehabilitation and repairing damage structural for example : bridge girder and beam building construction. To increase the shear strength , the externally bonded GFRP wrap can be applied continuously or discontinuously (strips) to a beam in general wrapping scheme:"U" wrapping, or fully wrapping. The aim of this study is to investigate the flexural capacity RC beams of shear cracked by using GFRP as a external strengthening . The fiber of GFRP sheets are placed in one layer (shear strengthening using continuously "U"wrapping). The test specimen were designed to shear failure in which shear span - to effective depth ratio is 1.56 and stirrups were spaced at a distance of 300mm. All specimens were tested under two-point static loading, the beam were incrementally loaded to failure. It is found that that externally bonded GFRP sheet can enhance the flexural capacity and also can change failure mode from shear-crack become flexural failure of RC beam.

Keywords- Shear crack, GFRP sheet, flexural, capacity,externally strengthening

I. INTRODUCTION

One of the main objevtives of design of reinforced concrete beam is safety. Sudden failure shear low strength is not desirable mode of failure. The reinforced concrete beams are designed primarily for flexural and shear strength. Beam are structural members used to carry loads primarily by internal mements and shears. In the design of a reinforced concrete member, fluxural is usually considers first, leading to the size of the section and the arrangement of the reinforcement to provide the necessary resistence for moment. For safety reason, limits are placed on the amounts of flexural reinforcement to ensure ductile type of failure. Beam are then designed for shear. Since shear failure is frequently sudden with little or no advanced warning, the design for shear must ensure that the shear strength for every member in the structure exceeds the flexural strength. The shear failure mechanism varies depending upon the cross-sectional dimension, the geometry, the types of loading, and properties of the member.

Normally, the inclined shear cracks start at the middle height of the beam near support at approximetely 45^0 and extend toward the compressive zone. Any form of effectively anchored reinforcement that intersects these diagonal cracks will be able to resist the shear forces to a certain extent.Crack pattern and shear modes of the reinforced concrete beam, the critical location for diagonal crack is between 1.5 and 2.5d from the support, where d is the effective depth, P is the concentrated load. The diagonal crack, when occur at 45^0 to the axis of the beam, cover distance of d along the axis[1]. The effective width of the GFRP deck that may be engaged is lower than that of an equivalent concrete deck. This decrease results from increased horizontal shear lag due to the less stiff axial behaviour of the deck (as compared to increase) and increased vertical shear lag do to the relatively soft in-plane shear stiffness of GFRP deck[2].

A lot of in-service civil structures are either structurally deficient or functionally absolute due tosequenly different seasons such as environmental deterioration, increase in design load, original construction faults, eartquake or external damage or change in use. To ensure satisfactory and safe performance, such structures need repair and strengthening. To meet this demand, external bonding of glass fiber- reinforced plastics(GFRP) to tension surface of the member has been proven to be effective strengthening method and has been wide – spread application. Consequenly, GFRP – strengthened concrete structure can fail suddenly due to the GFRP rupture or de-bonding of GFRP sheets.GFRP strengthening increased cracking load with increased in GFRP strip width and number of layers[3]. Effective procedure of wrapping enhance the strength considerably including the change of failure mode as well as change the location of failure plane and fluxural retrofitting also increases the shear strength of concrete[4].The deflection under fatigue loads was higher than deflection of static loads[5]. The proportion of the ACI 318-05, regarding the spacing of steel stirrups, has to be reconsidered to avoid shear failure when GFRP bars are used as longitudinal reinforcement for continously supported concerete beams with steel stirrups[6]. Fluxural retrofitting (with GFRP) also increases the shear strength of concrete. Figure 1. Typical wrapping scheme for shear strengthening using FRP laminates, illustration of the dimensional variables used in

shear-strengthening calculations for repair, and retrofit [7]. The contribution of the FRP system to shear strength of a member is based on the fiber orientation and assumed crack pattern[8]. The shear strength provided by the FRP reinforcement can be determined by calculating the force resulting from the tensile stress in the FRP across the assumed crack. The principles that apply to steel stirrups to composite reinforcement . The mayor differences are the force transfer mechanism and the high strength of the composite. The force is transferred through shear at the interface or mechanical anchors. The failure stress of the composite could be much higher than the yield strength of steel,fy.Once Vf is known, it can be added to the contributions of concrete,Vc, and steel,Vs, to obtain the total shear capacity,Vn.The shear contribution of the FRP shear reinforcement is then given by the equation :

$$Vn = Vc + Vs + Vf \quad (1)$$

$$V_f = \frac{A_{fv} f_{fc} (\sin\beta + \cos\beta) d_{fv}}{s_f}, \text{ where} \quad (2)$$

$$f_{fc} = \varepsilon_{fe} E_f \quad (3)$$

Where A_{fv} is the area of the composite reinforcement, d_{fv} is the depth to the composite, and s_f is the spacing of the composite reinforcement. The engle β is determined by the orientation of composite. The final parameter is E_f is material property,ε_{fe} is the effective fiber strain at failure.

The effective strain is calculated using a bond-reduction coefficient K_v applicable to shear :

$$\varepsilon_{fe} = K v_{fu} \leq 0.004 \quad (4)$$

The bond – reduction coefficient is a function of the concrete strength, the type of wrapping scheme used, and the stiffness of laminate. The bond-reduction coefficient can be computed :

$$Kv = \left(\frac{k1\ k2\ Le}{11900\ \varepsilon_{fu}}\right) \quad (5)$$

$$k1 = \left(\frac{f'c}{27}\right)^{2/3} \quad (6)$$

$$k2 = \left(\frac{df - Le}{df}\right) \text{for U wrap} \quad (7)$$

The active bond length L_e is the length over which the majority of the bond stress is maintained

$$Le = \frac{416}{(n \times tf \times Ef)^{0.58}} \quad (8)$$

Where t_f is the thickness of composite placed on both sides.

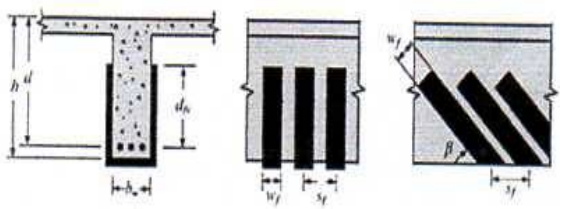


Figure 1Typical wrapping scheme for shear strengthening using FRP laminates

II. METHODOLOGY

2.1 Test specimen

The experimental study consisted of casting two groups . As shown Figure 3,the first group of RC beam without GFRP or control RC beam (CRC) and Figure 4, second group of RC beams with externally strengthening the of the RC beam U wrapping strips and Figure 5 the RC beams U wrapping continously with GFRP(GRC). The beams(26 Mpa) had a cross-section of 150x350mm with an overall length 3300mm (shear span - to effective depth ratio is 1.56). The beams were designed as balance reinforcement (fc=26Mpa),reinforced with 3Ø13 bar at bottom(fy=411.5 Mpa), 2Ø8 bar at top. Stirrup using 8mm @300mm(fy= 240.5 Mpa) .Tabel 1, show properties of GFRP for externally strengthening.

Properties of GFRP	Type of fiber (GFRP)
Tensile strength	3240 Mpa
Tinsel modulus	7240 Mpa
Maximum strain	4.5%
Nominal thickness per layer	0.36mm
Density	2550kg/m3
Weight	0.915kg/m2

Table1 Properties of GFRP

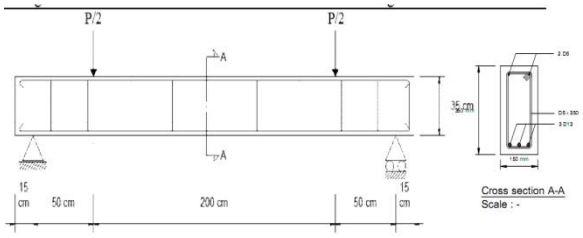


Figure 2 Detail of the test specimen of CRC

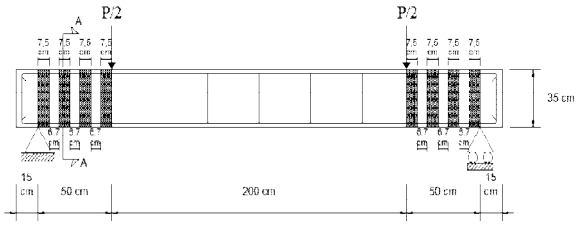


Figure 3 Detail of the RC beam U wrapping strips(GRC)

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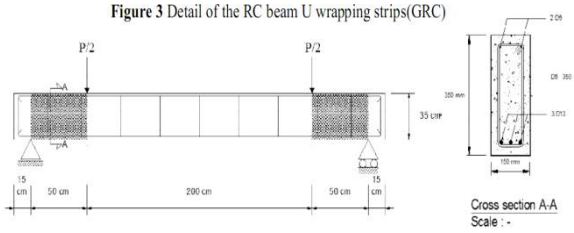


Figure 4Detail of the RC beams U wrapping continously(GRC)

2.2. Instrumentation and Testing Procedure

GFRP sheets were bonded to RC beams with a flexible type of epoxy resin. The GFRP sheets were bonded to the shear face of the specimen after 28

days of casting. The specimen were tested by using hydrolic jack and load cell.The specimens were tested under two-point static loading), Shear crack of the RC beams were retrofitted by The fiber of GFRP sheets are placed in one layer.

III. DISCUSSION

Table 2. show a typical maximum load- maximum flexural relationship of RC beams. As shown Table 2, control RC beams occurs maximum load - maximum flexural,respectively a 128.5kN- 64.3kNm, RC beam U wrapping strips 130.5kN- 65.3kNm, and RC beams U wrapping continously 136.5kN- 68.0kNm.

Condition of the Beams	Average Maximum Load (kN)	Average Maximum Flexural(kNm)
Control RC beams(CRC)	128.5	64.3
RC beam: U wrapping strips	130.5	65.3
RC beam:U"wrapping continuously	136.0	68.0

Tabel 2. Result obtained in experiment test

Figure 5 and Figure 6 show a typical crack pattern relationship of CRC and GRC. As shown Figure 5, cracks occured along the shear span 50cm from support for CRC and Figure 6, fluxural crack occured in the mid-span for GRC. It is found that that externally bonded GFRP sheet can enhance the flexural capacity and also can change failure mode from shear-crack become flexural failure of RC beam. One of the main objevtives of design of reinforced concrete beam is safety. Sudden failure shear low strength is not desirable mode of failure.



Figure 5. Crack Pattern CRC beam(shear Crack)



Figure 6. Crack Pattern GRC beam(flexural Crack in the midd- span)

The results showed that the increase was greater flexural on concrete beams using GFRP reinforcement when compared to concrete beams without reinforcement . This means that external strengthening with GFRP sheet along shear crack are able to increase the flexural capacity, but not significant.However, this results need futher the experimental study bycombining external retrofitting of the cracking shear and flexural for RC beams.The limitation of this study was the difference of the maximum load that occurs between CRC and GRC are relatively small.

CONCLUSION

The result from an experimental program have shown that externally bonded GFRP sheet U-wrap can enhance the flexural capacity and change failure mode of shear-crack become flexural failure of RC beam. Comparison of the percentage increase of the maximum flexural occurs between CRC and GRC of beams ,respectively:1.6%, 5.8%.

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