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Investigation of FRP impact on Shear Strengthening of Reinforced and Pre-Stressed Concrete Beams

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Abstract: The Fiber Reinforced Polymers (FRP) is a benefit for increasing and pre-stress concrete beams by adding FRP. The purpose of the study is to recognize the constraints impacting the shear capability added by FRP ، and assess the precise analyzing method. The experimental data displayed in the past illustrated that the obtainable systematic models used to predict the FRP capacity were in struggling to determine the incorporated plan. As a result, it may forecast exactly the shear involvement of outwardly practical FRP. Specific research figured out the comparison of experimenting data between the ACI 440.2R-08 method, and Triantafillou and Antonopoulos aiming to gain the satisfying assessment of FRP shear capability. The paper added visions into possible cases to unacceptable approximation.

Keywords:*FRP, pre-stress concrete, shear, reintegration.*

I. Introduction

Concrete assemblies get worse with time, therefore design method resulted in reorienting critical structural memberships like, beams which are essential. One problem that met those serious memberships is a shortage of supporting the applicable shear effect per time[1], [2]. Fiber-Reinforced Polymers (FRP) remained compound arrangements of fibers surrounded in a polymeric matrix as explained in[3], [4]. Reintegration of Reinforced Concrete (RC) elements by FRP usage was announced further than two eras back[5]. The researchers[3], [5]–[8] have revealed that using FRP to RC beams upsurges the complete shear volume of structuring element. According to a composite system of shear strategy even in easy supported concrete beams, resulting in the precise involvement to FRP in shear is fixed. The followed study outcomes are away and did not actually meet in the direction of a comprehensive forecast model [9]–[11].

The research review was focused to estimate the present case-run for shear-increasing of memberships usage FRP. Largely, Carbon Fiber-Reinforced Polymers (CFRP) whichever a greatest shared substance worked as a shear-strengthening [12]–[15]. The study has contained the assessment of prevailing investigational information verified through investigators with systematic methods which presently accessible in approximating the shear capacity providing via FRP[9], [16], [17].

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II. RESEARCH REVIEW ON SHEAR-STRENGTHENING BY MEANS OF FRP

Specifically, a review is offered through concerning numerous investigational research plans corresponding with the shear involvement of FRP. It is considered the most usable material used in shear-progressing of concrete beams. A study part similarly evaluates a present state regarding FRP usage of shear-strengthening concrete beams.

Effect of transverse steel and shear span-to-depth ratio on CFRP efficiency

Khalifa and Nanni experimented 12 samples of detailed scale beams[3]. Eight out of twelve were without transverse reinforcement of steel of (SO series) shear span with four transverse reinforcement of SW series. The beams are designed to test their failure in case of shear. Span/Depth ratios = 3 and 4 have been used. The samples are increased in power by adding continuous U-warps as in (Fig1: various FRP configurations (Adapted from Saset al.). The summation of these power fulling conformations was used with various fibre directions. The researchers investigated the impact of shear /span depth and interior strengthening of steel of externally bonded CFRP pieces[18]. Though samplings with transverse strengthening presented a lesser upsurge in shear volume than examples deprived of transverse strengthening of the shear span. The increase in sheer size was meaningfully reliant on the shear span-to-depth ratio a'/d.

The authors noted as well an 80% increase of span/depth ratio of 4 related to a 40% growth of depth to shear of 3, assumed a similar quantity of transverse strengthening in the shear span. The study also distinguished that the extreme upsurge in shear capacity was documented for the beam that wanted no transverse reinforcement. Also, required one constant U-wrapped CFRP layer of fibers which focused on to 90o by the beam axis. A discovery was later established with similar research directed by[7]. These researchers determined that outcomes they got to success CFRP strengthening decreases once both steel and CFRP strengthening are current. An upsurge in axial inflexibility of the CFRP with the difficulty of the transverse steel strengthening and the stiffness of the CFRP piece dropped the efficiency of the CFRP.

As it resulted from an assessment, that CFRP sheets could be more operative in beams deprived of transverse steel than of beams with transverse reinforcement

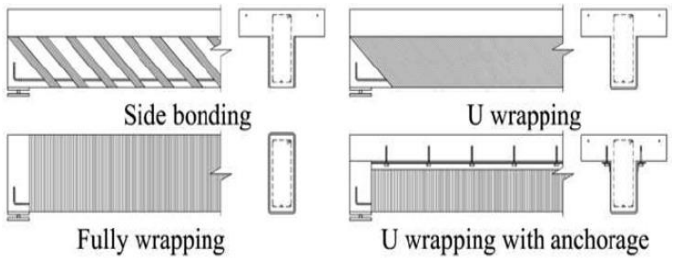

Fig 1: Various FRP configurations (Adapted from Sas et al.)

Shear disappointment apparatus of RC beams reinforced with CFRP

Authors of study[7] showed an investigational research in detecting and assessing a dissatisfaction apparatus of beams supported through increasing side-bonded CFRP slips. A stiffness factor was determined as a ratio among transverse shear strengthening and CFRP shear steel (ρs,f). A characteristic of the shear-tension fail was detected for the beams which required neither transverse nor CFRP shear strengthening. The study detected that all verified samples deprived of transverse steel showed the main crack sketch in a sub-horizontal way with the direction of around 45º close the opinion of request of the weight. A numeral of CFRP layers practically would not change the forms of breaking the beams. Nevertheless, one sheet of CFRP was sufficient to extremely change a

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fail style of the beam, as was also the situation for the beams supported with two or three sheets

In similar practical research, this research also verified samples with transverse steel strengthening. Samples with ρs,f of 1.37 and supported by one sheet of CFRP showed disappointment according to shear cracks inclined by 45º.

The samples displayed cracking shapes as same as the beam with no CFRP excluding those of excess yielding behavior close to failing. The samples with ρs,f between (0.46-0.48) presented cracks of closeness region of cracking the concrete cover. As in the same cases produced by[3]. Recognizing that samples with U-wraps or sideways ties will not display breakage or debonding from the concrete apparent at[3]. Though, samples by dual films of sheets verified by[6]exposed rupture length, the way equivalent to the CFRP fibers. The research similarly demonstrates which debonding was not normally detected for beams supported by flat associated threads.

In examples with small depth, last dissatisfaction happened in concrete owed to unique dangerous crack, while the beams of an advanced layer complexity failed with concrete severe and crushing. In[19]showed an investigation to notice that the shear disappointment apparatus of RC beams supported with (GFRP), (CFS) and CFRP. A detected that the firming material did not drop the shear cracking form of the RC beam. Most of beams were unsuccessful succeeding the characteristic oblique shear breaking shapes as it can be seen in Fig 2:Cracking forms (Adapted from[19]).

The firming resources were uncertain with an angle vertical to fibre location. They detected which cases that reinforced a 45º CFRP slip are not resulted in the characteristic oblique shear cracking design. As a result, it detected in specimens supported with 90o or 0o fibre direction. Additionally, this created that the examples supported with CFRP strips concerned with 45o established shear cracks that developed vertically to the bottom.

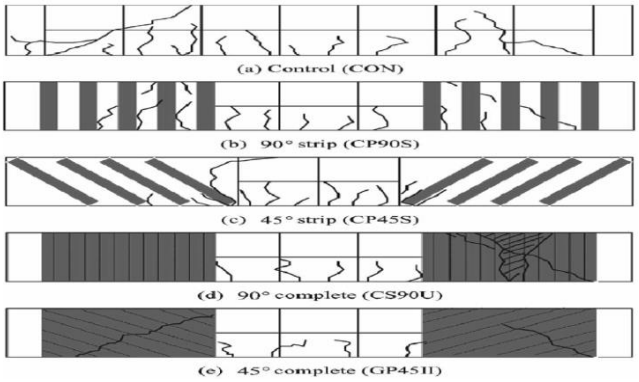

Fig 2: Cracking forms (Adapted from [16]).

RC beams performance of shear-reinforced of different FRP forms, sheet conformations and plans

Adjust of concrete memberships with CFRP slips is a well-organized and profitable technique. Though the method had remained familiarized, engineers may consume different sheet formations of FRP. Altogether, changed the performance of the RC beam dependent on in what way the FRP was used. In[6] verified eight beams that required various (CFRP) sheet outlines with the lowest point. The total examined beams be located and planned to unsuccessful in shear. The beams are usable in the investigational package was not take interior shear strengthening in the shear length. The rupture strength in[6] the paper illustrated that a rupture strong point of a carbon fibre piece composed by straight-up fibers is larger than divergence strength of a carbon fibre piece with level threads, up to[6] it can be found that growing the sheet depth by fifty% lead to in a 108% upsurge in shear volume of samples (a 50% upsurge from the innovative depth).

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Samples supported of extra pages of sheet presented only a 3% upsurge in final shear strength associated to examples deprived of added sheets of CFRP. Probably,[3] described an upsurge in shear measurements was not relation to the growth in CFRP quantity. Throughout an investigational research showed of[3] samples are being reinforced with 3 inch. Extensive strips spread out at 5 in showed the similar fail mechanism and did not produce an important surge in shear volume related to samples reinforced with 2 inch. Notice that even a 50% upsurge in the CFRP band range did not make an obvious rise in the shear volume of the beams.

In[19] experienced the performance of RC beams enlarged their shear with GFRP, CFS and CFRP and originated to the discussion that did not display an association in firming impact. The authors similarly saw that once beams were supported of a 45o fiber alignment, the firming up impact was enlarged by further than 10% in every sample associated with examples with 90o fiber location.

Prestress concrete beams behavior

CFRP in prestressed concrete (PC) of shear supported was extensively used in construction, particularly for bridge and beams. In structure elements, repairing the members is frequently wanted once the bridge is satisfying overloaded circulation. Writers have in progress to move their concentration on fixing RC members to mending PC memberships using outside CFRP; though, here is a deficiency in a study on shear-strengthening of the PC memberships with CFRP.

In[20] focused together on shear and flexural examinations on three occupied measured bridge girders that were substituted by the Kansas Department of Transportation. A confirmed two beams by no extension (NOH) and three girders by projection (OH). An examination arrangement added a considerate effect of CFRP on the circulation of web shear blows into the transmission distance of the prestressing steel[21]–[24]. Additional research[25] presented that the disappointment style of PC girders supported in shear with externally attached FRP was affected by the stiffness of top and bottom flanges and debonding of the FRP.

III. VALUATION IN PRECEDING INVESTIGATIONAL INFORMATION

In this specific part, an explanation of the valid test data with the existing analysis models is discussed. This amplification of the valid data aids to find the limitations that include a convincing influence of shear involvement of CFRP.

Investigational information on significant parameters

In the overview of CFRP shear-strengthening system, two or three investigators been accumulating investigational data to improve the prediction of the shear involvement of CFRP.[26]–[28] have collected an intelligent list of investigational data beginning from more than 30 changed educations directed on RC beams, and the list had been restructured by[29]. A database takes over 150 beams supported with CFRP, Aramid FRP and GFRP. This segment mainly examines the restrictions applied strictly to beams reinforced with CFRP[27], [30].

In[27], the study restrictions covered the compressive strength about concrete, the inner transverse strengthen shear strengthening, a longitudinal steel support, the shear to span s/a ratio with an association among the functional CFRP formation.

$$\text{Increase in shear capacity due to CFRP}(\%) = \frac{V_f}{(V_t - V_f)} \times 100$$

where Vf considered as the ration between the control / strengthen specimen and Vt is the entire

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shear value of the beam. That growth was considered as the basis for calculating the impact of the above-mentioned limitations as it can be seen in Fig 3: Relation between the compressive strength of concrete with upsurge in shear according to CFRP. Displays a communication among the fc' of concrete and the shear upsurge according to CFRP. To count an impact of the compressive strength contrary to the CFRP, the ratio of (Efρf / f'c) 2/3 was determined, wherever Ef is the ES of the CFRP, ρf is the CFRP proportion and f'c is the compressive strength of the concrete.

An overall tendency resultant from this diagram is that the rise in shear up to CFRP seems to develop extra necessary the proportion of (Efρf / f'c)2/3. This illustrating samples built with an advanced compressive strength which display a lesser upsurge in shear volume according to CFRP request. The tendency is reliable up to a value of (Efρf / f'c 2/3 = 8). Ef is the elastic modulus of the CFRP and ρf is the CFRP shear steel ratio [2] Fig 4: Interaction between internal transverse shear reinforcement.

The over-all tendency at this time is the involvement in shear value of the CFRP declines with the percentage of (Esρw / Efρf). By increasing the internal steel in a specimen, the upsurge in shear will be less due to CFRP.

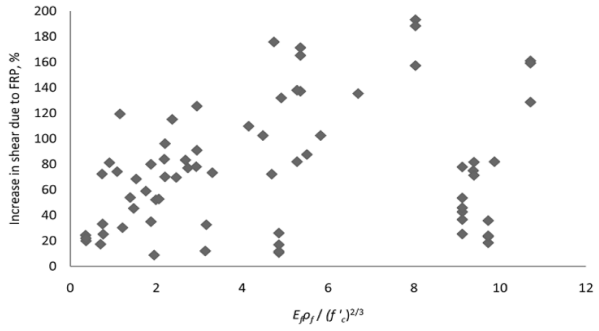

Fig 3: Relation between the compressive strength of concrete with upsurge in shear according to CFRP

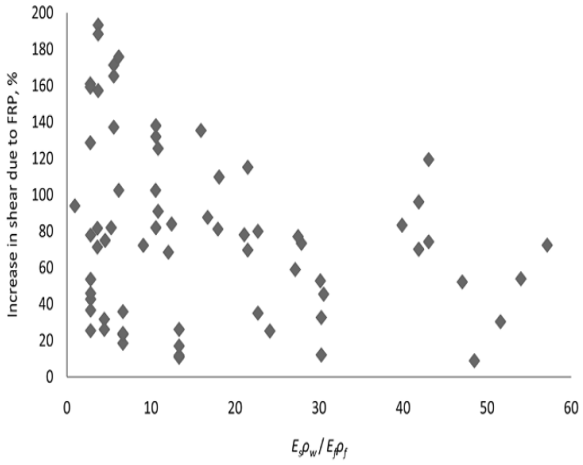

Fig 4: Relation of internal transverse with shear reinforcement

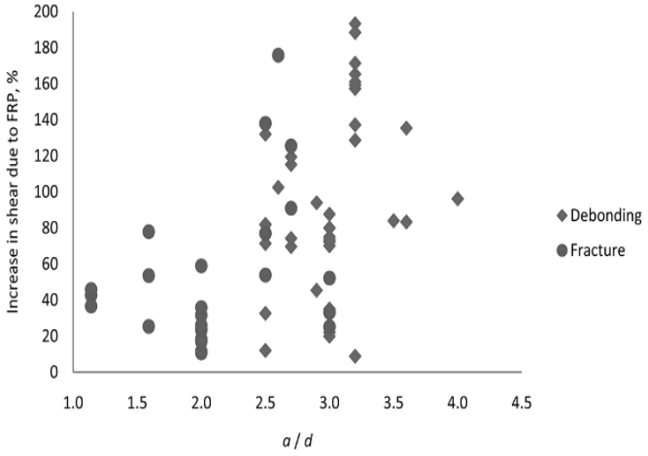

Fig 5: Relation of shear a'/d ratio percentage with upsurge in shear according to CFRP with impact of fail form surge of shear corresponding to CFRP

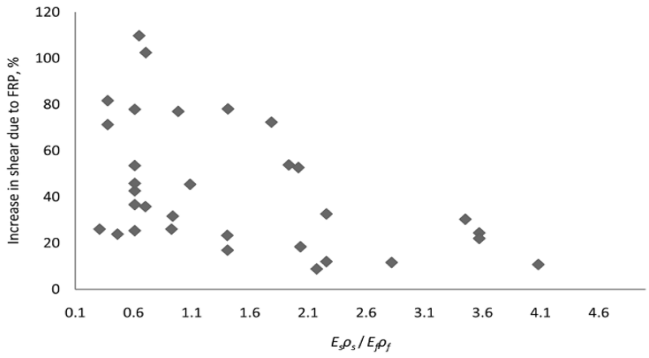

Fig 6: Relation between shear span-to-depth ratio with upsurges in shear according to CFRP

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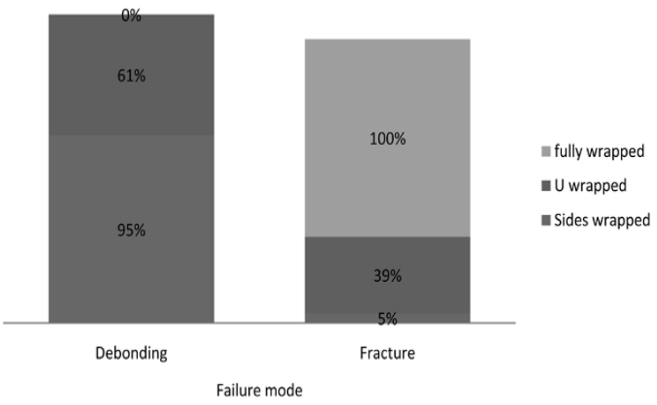

Fig 7: Interaction between disappointment manner and CFRP

$$\text{Increase in shear capacity due to CFRP}(\%) = \frac{V_f}{(V_t - V_f)} \times 100$$

An interpretation around specified chart was similarly long-established by[3]whose discovered an upsurge in shear remained more important in samples with no transverse strengthening than of samples of transverse strengthening. The (a'/d) seems to remain a significant limit. As in Fig 5: Interaction between shear span-to-depth ratio and increase in shear due to CFRP and the influence of the failure type increase in shear due to CFRP, displays that as the (a'/d) proportion upsurges the shear involvement of the CFRP. Also, the contribution between the sort of fail of the samples and the (a'/d) proportion is distinguished. It was originated in Fig 5: Interaction between shear span-to-depth ratio and increase in shear due to CFRP and the influence of the failure type increase in shear due to CFRP that greatest of the verified samples by an (a'/d) fewer than or equivalent to 2.5 was unsuccessful by CFRP break. Whereas samples by (a'/d) larger than or equivalent to 2.5 was unsuccessful by FRP deboned. The specified info shows that beams belong a comparatively brief shear distance tend to practice break of the CFRP throughout charging. While for beams by comparatively lengthier shear span, the CFRP piece is probable in debonding the concrete throughout charging. Moreover,[3] founded that the shear growing is surged and doubled in some points for examples have an (a'/d) of 4, in comparison of samples with an (a'/d) of 3. The increase requests around the efficiency of CFRP in deepness beams, meanwhile they consume a lesser (a'/d) (for a standard shear width distance of a'). The study of [31] connected the gage impact of the significant of the tie superficial zone.

The bottom of the beam is significant to the CFRP influence up to shear aggressive; so, a quantity of CFRP might essential to considerably enlarge the deep beams. Additional investigation might be wanted to strengthen the shear of deeply beams using CFRP. The longitudinal steel, even still used largely for the flexural strengthening, consumes the positive effect of shear performance of CFRP[27], [31], [32]. As in the Fig 6: Reaction between shear span-to-depth proportion with upsurge in shear according to CFRP demonstrated that the major upsurge in shear owing to CFRP was verified of samples with a minor quantity longitudinal steel.

As a result, in samples with longitudinal steel, the upsurge in shear according to CFRP resulted in declining the percentage of the number of (Esρs / Efρf). Which rises according to a value of around 3. It illustrates that the involvement of CFRP is condensed of samples through a comparatively big quantity of longitudinal strengthening as in Fig 7: Interaction between failure mode and CFRP. In the Unwrapped examples (CFRP practiced on three edges in a U shape), debonding was experienced for 61% of the verified beams whereas a slight over 1/3 of the entire U-wrapped examples presented break of the CFRP at disappointment. The side-attached examples unsuccess enormously (95%) with the CFRP debonding from the concrete at disappointment and only 5% of side-attached beams are un successes with the CFRP existent cracked as in Fig 7:Interaction between failure mode and CFRP. Also demonstrates that debonding of the

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CFRP is a thoughtful subject particularly in side-attached examples. The deboned seems normal for fully wrapped examples. A clear deduction could not be drawn for the U-wrapped examples possibly according to the diverse shear span-to-depth ratio which acts a significant character in the disappointment style of the verified examples.

Existing investigative models Valuation to evaluate FRP shear involvement

The specified part reviewed double investigative models. Together imitations industrialized to assess the shear influence in externally bonded (FRP) which was reorganized by[28].

The predicted Triantafillou and Antonopoulos method

Triantafillou and Antonopoulos definite an entire shear involvement in FRP where γfrp is a fractional care feature for FRP (1.15 for carbon), be considered the width of the web of an element [33]–[35], ρf representing the zone portion, εfe is the impactive straining FRP, Ef considered as rigorousness of FRP, β is a perspective of fibre way to the longitudinal axis of the element with Vf of the additional sheer capability of the FRP. The following analyses method presented the impactive strain (εfe) of the FRP into the estimation of the additional capability of FRP shear. Moreover, it deliberated the kind of FRP with conformation strength and the impact of FC' on FRP strain.

In the Fig 8: Triantafillou and Antonopoulos model prediction for several beam section types. Triantafillou and Antonopoulos together with resulted in experimental values gotten, similarly relating the various FRP outlines (i.e., sideways-attached, U-wrapped and completely enfolded). A primary opinion is resulted with the specified method under estimation of the shear influence of FRP in entirely enclosed samples. For example, reinforced by side-attached or U-wrapped FRP as inFig 8:Triantafillou and Antonopoulos predicted method to several beam section kinds demonstrated that for greatest of the U-wrapped specimens, the representation's forecast is near to the experiments principles and in greatest cases overrates the involvement of FRP to the total shear measurements of the beam. For side-attached samples, the representation's forecast is not as good as for U-wrapped samples. Meanwhile, this method does not reflect the bond instrument among the FRP and concrete[26]As shown in Fig 9: Triantafillou and Antonopoulos predicted method for various beam section types.

The predicted method of ACI 440.2R-08:

FRP analyzing method of ACI 440.2R -08 identify the involvement of shear as:

In[6] where Vf means the additive shear capability of the FRP, df illustrates the operative deepness of FRP, sf considered the spacing of FRP floorings, ffe considered the operative stretchable FRP stress and Af means the part of FRP. Whereas, the model sophisticated by[31] includes the tie apparatus that occurred among the concrete with an applicable exterior FRP strain which may be attained by the FRP to 0.4%. The ACI 4401 investigative method presented the bond-reduction constant (κv), which is considered a purpose of the strength of concrete, a consolidation confirmation with the stiffness of the FRP.

A tie decrease constant (κv) is definite in ACI 440 as wherever le is the energetic tie distance distinct as the span completed that the widely held of the bond stress is preserved, k1 is an alteration issue which is a purpose of the concrete strength, k2 is an alteration feature that is a purpose of the firming formation and εfu is the final strain of the FRP. An operative draining derivative of a process is definite like:

$$V_f = \frac{A_f f_{fe}(\sin\beta + \cos\beta) d_f}{s_f}$$

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$$\kappa_v = \frac{k_1 k_2 l_e}{468\varepsilon_{fu}} \le 0.75$$

$$\varepsilon_{fe} = \kappa_v \varepsilon_{fu} \le 0.004$$

Fig 10: Triantafillou and Antonopoulos predicted method for different beam section kinds displays a judgement among the ACI 4401 method forecast the investigational standards.

The FRP shear influence remained connected to numerous stiffening conformations as in Fig 10: Triantafillou and Antonopoulos of predicted method of different beam section kinds. It obviously displays that an ACI method estimates the FRP shear measurements of wrapped samples. When we have an unwrapped or side-attached samples, a method illustrates dispersed information around the investigational standards, of greatest side involved samples being valued. In comparing a technique with Triantafillou and Antonopoulos' method, it displays further dispersed data around the line. The ACI 4401 prediction displays the estimation of FRP shear involvement in four-sided beams conferring to Fig 10: Triantafillou and Antonopoulos of predicted method of different beam section kinds.

Extreme suppositions resulting from the specified model of rectangular beams considered safe in comparison with separate lines of experimental principles. It is combined to the real that bonds decrease bonds in energetic to decrease an assessed magnitude. A comparison of Triantafillou and Antonopoulos method with the ACI 4401 predicted method has an accurateness in predicting the FRP shear involvement of rectangular beams as in Fig8: Triantafillou and Antonopoulos predicted method for different FRP configurations. Fig 10: Triantafillou and Antonopoulos predicted method for different beam section kinds. For T-beams, the ideal estimates of the FRP involvement the shear measurements of the samples. The specified method seems an appropriate to conventional plan of fully wrapped rectangular examples as in Fig9: Triantafillou and Antonopoulos predicted method of different beam section kinds and Fig 11: ACI 440 model prediction for various beam section types.

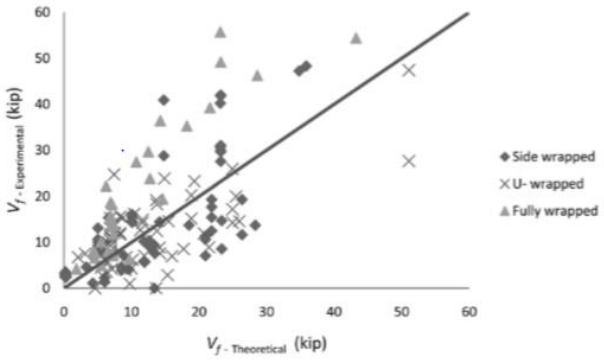

Fig 8: The predicted method of Triantafillou and Antonopoulos different FRP involvement

IV. CONCLUSIONS

An intensive method in up surging the reinforcing shear strength with pre-stress elemental concrete in adding FRP had been discussed. In the specific review through using the widespread collected Data of the previous studies, the parameters impacting the shear measurements of externally complex CFRP had been recognized with an accurateness of analysis methods. Depending on this study, a conclusion been prepared.

The shear rise according to CFRP is more for low compressive strength concrete of longitudinal strengthening. The shear capability in the CFRP declines when interior steel reinforcing is soared. On the other hand, the capacity surges once the proportion of span to depth is increased.

Additionally, larger span/depth ratio has more debonding. The results from the prior experiments clarify that the accurateness of the method advanced by Triantafillou and Antonopoulos in estimating strength ability of rectangular beam is good, whereas the forecast for T-beams and many

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four-sided beams are unsafe. The same trend is found in the case of ACI 4401 method, by presenting extra scatter than the Triantafillou and Antonopoulos model.

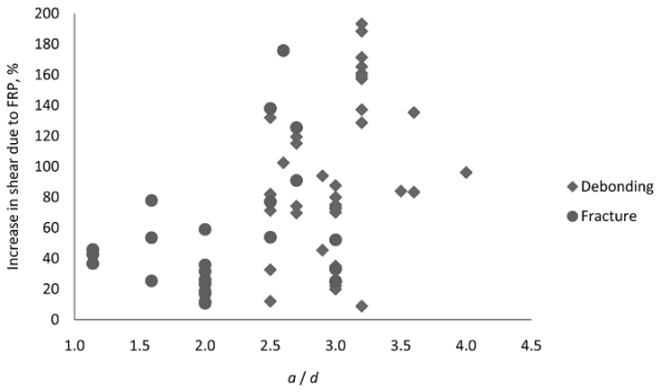

Fig 9: Triantafillou and Antonopoulos predicted method of different beam section kinds

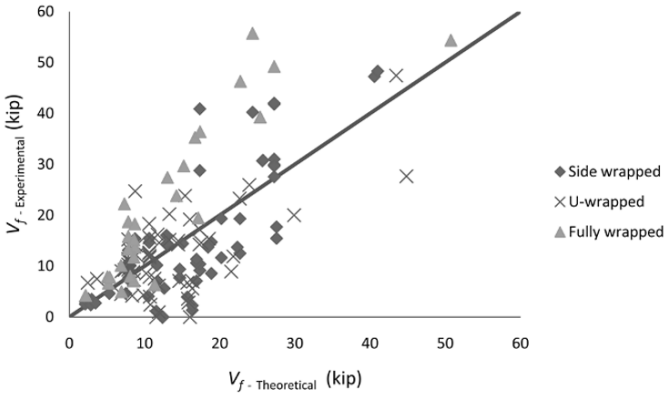

Fig 10: Triantafillou and Antonopoulos predicted method for several beam section kinds

Additionally, by increasing the span/depth ratio, the debonding will result. Both methods may be conventionally being suitable for the completely enfolded FRP, through this applicant is not mutual. Though, both models are un safe to be applicable to the side-attached FRP. As occasioned from a relating with the preceding investigational Data, the accuracy of the process of Triantafillou and Antonopoulos in forecasting the capability of reinforced four-sided beams is comparatively good.

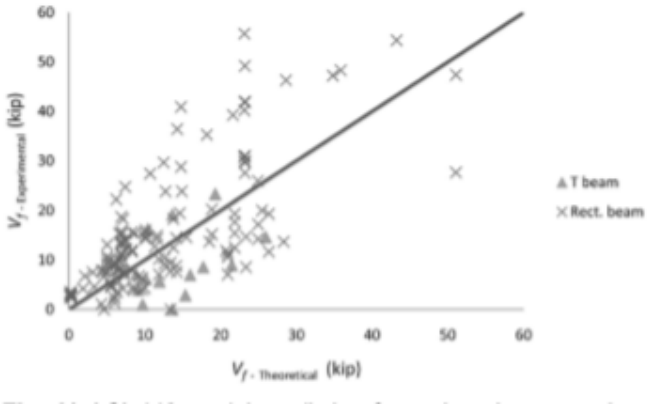

Fig 11: ACI 440 predicted method of different beam section kinds

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