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Finite Element Modelling of Reinforced Concrete Beams With a Hybrid Combination of Steel and Glass Polymer Reinforcement

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Abstract: In this study, finite element modelling of hybrid reinforced concrete beam (HRCB) will be constructing in Atena Engineering 2D Software referring to experimental data from previous testing investigation at laboratory. Steel reinforcement was used in HRCB because it has high modulus of elasticity and improved the tensile strength and certainly for shear strength. While GFRP reinforcement had low, modulus of elasticity but it can protect steel reinforcement bar to the durability against corrosion various with steel. Based on the result of load deflection obtained while analysed the result of finite element modelling in Atena engineering software, it obtained the maximum load before move to failure mode for all type of reinforced concrete beam and the result had been compare with experimental data to achieve the validation between it. The result analysis of HRCB of finite element modelling from Atena Engineering 2D software had proved the validation with experimental data. The percentage of validation for HRCB which is 2.3% of BS control beam and 2.8% of BG control beam, 2.2% of BH-1, 2.7% of BH-2, 2.8% BH-3, 0.01% BH-4, 1.7% BH-5 and 0.7% BH-6 of hybrid beam. The crack pattern obtained in this study after load applied on the beam that produced the type of failure for Hybrid RC beams which is; Flexural failure of BS, Flexural and shear failure of BG, Flexural and Shear failure of BH-1, Flexural failure of BH-2, Flexural and Shear Failure of BH-3, Flexural Failure of BH-4, Flexural and Shear Failure of BH-5 and Flexural Failure of BH-6. This study also analysed the load deflection parametric of the effect on materials properties of four types of FRP bars which is; Basalt Fiber Reinforced Polymer (BFRP) , Aramid Fiber Reinforced Polymer (AFRP), Glass Fiber Reinforced Polymer (GFRP) And Lastly, Carbon Fiber Reinforced Polymer (CFRP). As a result, CFRP was produced the highest maximum flexural load that was because CFRP had providing the highest contribution of all types of FRP bars such as it had highest of stiffness, flexural strength, ductility as well as toughness. However, BFRP was the highest duration of time before reached the failure mode.

Keywords: Hybrid Reinforced Concrete beam (HRCB), Validation, Crack pattern, Load Deflection Parametric

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1. Introduction

The most caused of beams reinforced concrete failure is because of the weakness which is corrosion impact of a steel reinforcement through environment with different area [1]. By choosing GFRP as a alternatives reinforcement bar to replace some of steel reinforcement bar in hybrid reinforced concrete beams is the best choice because polymer have corrosion durability characteristic which is steel reinforcement exposed to the water and a long time of elongated strain to failure is enough to be alert before failure occurs [2]. However, reinforced concrete only used GFRP as a reinforcement bar are not suitable because GFRP have low modulus of elasticity compared with steel reinforcement bar that have high reinforcement ration that are needed in beam composite component and Flexural stiffness of GFRP bar relatively less than steel reinforcement bar and more deflection and cracking approved in traceability of GFRP reinforced concrete design [3]. In some researches also proved that, GFRP bar in reinforced concrete has been shown that the good result which is have no any degradation process subjected to it when coming in surrounding of alkaline and corrosive environment [4].

Steel and Glass polymer reinforcement bar are suitable combination that because it can depend with each other [4]. By proposing the Hybrid Reinforced Concrete Beam (HRCB), based on some testing shown, yield happen on steel bar produced the durability of beam and high tension strength of GFRP could increase the bending power after yielded [2]. Atena Software used to conducted of the finite element modeling analysis [5]. To obtained the result and verification of Finite Element Modelling for beam, Figure 1 shown the graph of load deflection of the experiment data as well as for finite element modelling analysis has been plot [6].

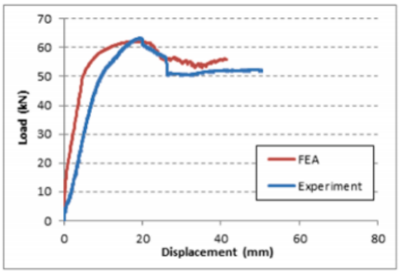

Figure 1: The results of Control beam SR for Finite Element analysis and Experimental data[6]

Nowadays, FRP bar made from glass, carbon, aramid as well as basalt commonly used in concrete as an alternative to the steels bars [7]. During inspect the effect of type of bar to the flexural strength, steel reinforce concrete beam is the highest flexural strength compared to the others type of bar. The increases of flexural strength around 57% for steel reinforcement specimens and 50% for AFRP reinforcement specimens and 33% for BFRP reinforcement specimens, and 56% for CFRP reinforcement specimen as well as 40% for GFRP reinforcement specimens. Steel reinforced shown the highest percentage of flexural strength. The percentage different for FRP bar to steel bar that were for CFRP was 1% only and then, for AFRP was 5%, and for GFRP was 12% and lastly, for BFRP was 18% [8].

2. Materials and Methods

This part is representing the methodology that explains the implementation that has been carried out to achieve the objectives of the study. Details of the procedure and technique also were provided to produce the finite element modelling and analysis data.

2.1 Description of the Structure

The Hybrid reinforced concrete beam (HRCB) is design and analysis experimental of laboratory testing from previous investigation. The size of control and hybrid RC beams is 250 x 200 and the length of beam is 2000mm. Besides that, the detailing of beams specification has been shows in Table

1. There have eight modelling with two different types of supports, which is pinned, and roller has been design from previous experimental data of laboratory testing. Based on Table 2, it shown the material properties of finite element modelling will be assign in Atena Engineering 2D Software refered to Experimental data. There have eight modelling with two different types of supports, which is pinned, and roller has been design from previous experimental data of laboratory testing. Figure 2 until Figure 7 were shows the dimensions and specimens of Control and Hybrid RC beams.

Table 1: Beam specification details

Sample	Steel reinforcement	GFRP reinforcement	Stirrup	Remarks	Reinforcement ratio, ρ
BS	3Y12	-	R8-200 c/c	Control beam	8.228×10^{-3}
BG	-	3G13	R8-200 c/c	Control beam	9.66×10^{-3}
BH-1	1Y12	2G13	R8-200 c/c	Hybrid beam	9.175×10^{-3}
BH-2	1Y12	2G13	R8-50 c/c	Hybrid beam	9.175×10^{-3}
BH-3	1Y12	2G16	R8-200 c/c	Hybrid beam	0.013
BH-4	1Y12	2G16	R8-50 c/c	Hybrid beam	0.013
BH-5	2Y12	2G16	R8-200 c/c	Hybrid beam	0.015
BH-6	2Y12	2G16	R8-50 c/c	Hybrid beam	0.015

Table 2: Materials Properties of Finite Element Modelling

Type of Materials	Compressive Strength (Fck)(Mpa)	Compressive strain	Modulus elasticity of Reinforcement (Mpa)	Stress-strain law	Tensile strength (Mpa)
Concrete	30.9	0.003	-	-	-
Steel Bar	-	-	200000	Bilinear	550
GFRP bar	-	-	44100	Linear	-
Stirrups	-	-	162000	Bilinear	250
Steel Plate	-	-	210000	-	-

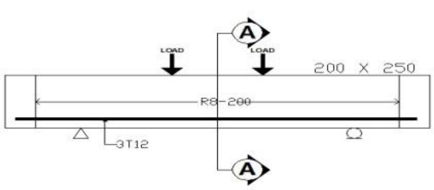

Figure 2: Reinforced concrete beam design with R8-50c/c stirrup

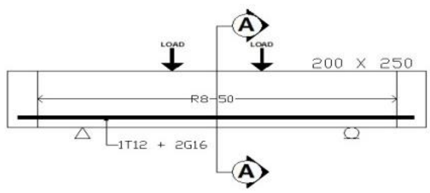

Figure 3: GFRP reinforcement bar

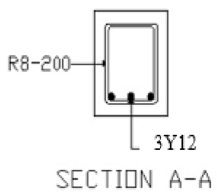

Figure 5: Steel reinforcement bar

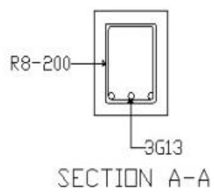

Figure 6: GFRP reinforcement bar

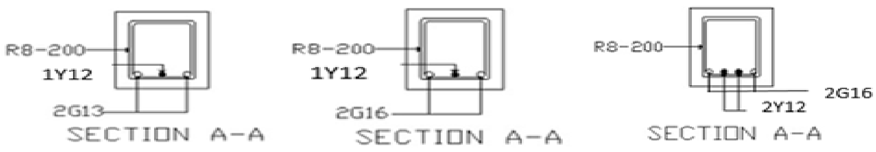

Figure 7: Hybrid reinforcement bar

2.2 Modelling work By Using Atena Engineering Software

Atena Engineering 2D software will used to produce the finite element modelling of Reinforced Concrete Beam of Hybrid combination of steel reinforcement and GFRP reinforcement based on the dimension and parameters from previous experimental data from laboratory testing. Based on Table 2, it shown the material properties of finite element modelling will be assign in Atena Engineering 2D Software refered to Experimental data. The second step was setting up the topology in Atena Engineering software that have several types of parameter has been assigned which is Joints, Lines, Macro element as well as Bar reinforcement. Firstly for joints, clicked the button Joints and continued to clicked the Add button and then, assign the coordinate of X –axis and Y-axis for all types of Control and Hybrid RC beam based on Table 3. Then, for lines, clicked the Line button, and then, click the button + on the Atena Engineering 2D software and then, pulled the line from one joint to another joint until finished. In addition, for macro elements, first, choose the Mesh type, which is Quadrilaterals and then continued with assigned the element size in between 0.003mm until 0.008mm. Then, assigned two types of materials for macro element which is Steel plate at the supports and load area and concrete at Control and Hybrid RC beams location and after that, assigned the thickness of the beam that was 0.2m and lastly, chose the Quadrilateral elements which is CCIsoQuad. There have two type of cases has been assigned in the Atena Engineering 2D software which is Support and Load. Firstly, click the load cases button, then, clicked Add and after that, typing the LC name for support of load case number 1, then, chose the LC code that was Supports and will continued with assign the Load case number 2 with the same method. After that, Active LC1 for support and continued clicked the joint button and assigned it to support area and then, clicked line and put at the half of beam line as a joint support for the beams and then, Active the LC2 for load and continued with clicked the joint button and assigned it to load area.

Result and data analysis was getting from Finite Element Modelling of Control and Hybrid RC beams on Atena Engineering Software with several types of analysis will observe in this study, which is load deflection, type of mode failures, as well as crack pattern. The result of mode failure could be obtained based on the crack pattern appeared on the RC Beams. Before getting the result analysis of finite element modelling, it needed to assigned several types of parameter which is setting up the solution parameter, clicked Add button for assigned solution parameter of Finite Element Modelling, and then, chose general and change the iteration number limit from 60 until 80 and then, clicked the line search. After that, changing the solution method to 'with iterations' and the line search limit was around 0.001[-] until 1.000[-] and the lastly, chose the Conditional Break Criteria and changed the Break after step to 10.0[-] for Displacement error multiple, Residual error multiple, Absolute residual error multiple and 1000[-] for Energy error multiple. After that, moved the procedure from assigned Solution Parameters to Analysis steps, the Analysis steps had assigned around (140- 250) until the beam showed the failure mode and has been achieved maximum load during the analysis. Then, moved to assigned the monitoring point for Load which is clicked Add button and then changed the Name Title which is LOAD and then, setting the Location of the monitoring point for load which is X-axis was 0.795m and Y-axis was 0.275m. After that changed the value of monitoring point to Reactions and chose Component 2 for item, and lastly, assigned the coefficient Multiplier from 0.0[-] until 2.0[-] based on the result obtained. when the result of finite element modelling showed the similarity quite far from experimental data, the Coefficient Multiplier will be changes until the result showed the validation between Finite Element modelling and Experimental Data. Then, add another Monitoring point for Deflection, firstly, changed the Name Title to Deflection as well as setting the location for monitor the Deflection during analysis that was for X-axis (0.995m) and Y-axis (0.005m) and then, changed the value of Monitoring point to Displacement and then, changed the coefficient Multiplier around 0.0[-] until 2.0[-]. Finally, clicked Add for another Monitoring Point for Concrete strain, firstly, changed the Name Title to Concrete Strain and then, setting the coordinate of the location to monitor the Concrete strain, which is X-axis, was 1.000m and Y-axis was 0.250m. Then, changed the location types to Integration points as well as changed the value of monitoring points to Strain and then, chose the component 1 for item part. Figure 8 shown the modeling of Control and Hybrid beams.

After all had assigned for the analysis result, lastly clicked the button Run finite element analysis and then, changed the coordinate of initial data for LD-diagram, which is X-axis was deflection and Y-axis was Load and then clicked Analyse. After that, the result will be analyse and shown the crack pattern on the beam until the Hybrid and Control RC beams were failure. After finished the analysis and then, chose Step button of the result and changed it to the last steps of analysis and after that, clicked the Cracks button and then, chose the element to saw the crack pattern on the Control and Hybrid RC beams to investigate the mode failure were obtained during the analysis and then, clicked windows and chose new and then chose graph. For the graph, changed the coordinate name, which is for X-axis for Deflection, and for Y-axis for Load and then, saw the graph whether the maximum load of finite element modelling has been achieved the similarity with experimental data. After that changed X-axis to Concrete strains and then, the graph shown the maximum of concrete strain has been achieved 0.003, the RC beams has been failure.

Table 3: Coordination of Joints of Finite Element modelling based on the dimension from previous experiment

Joints numbers	Coordinate		Joints numbers	Coordinate	
	X-axis (m)	Y-axis (m)		X-axis (m)	Y-axis (m)
1	0.0000	0.0000	8	1.0000	0.0000
2	0.0000	0.2500	9	1.0000	0.2500
3	0.2000	-0.0300	10	0.8500	0.2500
4	0.2000	0.0000	11	0.8500	0.2800
5	0.2500	-0.0300	12	0.8000	0.2800
6	0.3000	-0.0300	13	0.7500	0.2800
7	0.3000	0.0000	14	0.7500	0.2500

In this study, result and data analysis are getting from finite element modelling of all types of RC beam design on Atena Engineering Software. Before that, the step to getting the result was in sequences from setting up the solution parameters for finite element modelling, then, inserted the number of step analysis for both load case which is Load Case With Support (LC1) and Load Case With Action (LC2) and then, inserted the monitoring point for location to monitor reaction of load, displacement of deflection as well as strain of concrete and the lastly, run the finite analysis for all types of beam that has been stated in Table 1. Based on Figure 9, shown the finite element modelling after assign the analysis procedures. After all the procedure to getting the analysis has been assigned. There have several type of analysis will observe in this study, which are load deflection, type of mode failures, as well as crack pattern. Crack width will appeared when the load has been archived maximum load and from the result mode failure will appeared when the concrete strain achieved ultimate of compressive strength. Then, compare the validity of load deflection between experimental data and Atena Engineering Software. In addition, the crack pattern between both experimental data and Atena Engineering software also will be compare. There have several steps to get the result data from Atena Engineering Software finite element modelling. The method were same to contruct the modeling for the effect of parametric study with each types of RC beams and GFRP bar were changing to the another types of FRP bar which is Basalt Fiber Reinforced Polymer(BFRP), Carbon Fiber Reinforced Polymer (CFRP) and Aramid Fiber Reinforced Polymer (AFRP).

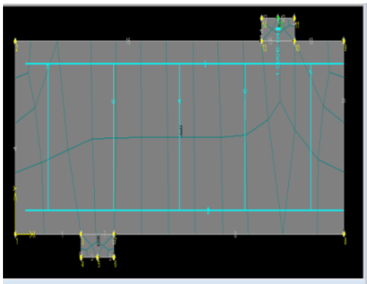

Figure 8: Modelling of finite element of Control Hybrid RC beams

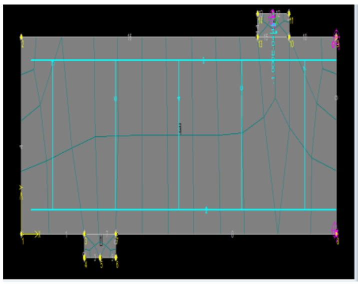

Figure 9: The modelling after assign the anasyis procedure.

3. Results and Discussion

This part presents the results of the conducted on eight result of finite element modelling of Control and Hybrid RC beams had obtained that compared to analysis result from testing experiment of beams structure. There have some of dynamic characteristic of every finite element modelling has been analyzed from Atena Engineering software that were the process to getting load deflection as well as width cracking for every types of beam which is control beams and hybrid beams. The parametric studies that are the effect of materials properties of four types of Fiber Reinforced Polymer (FRP) that are Aramid Fiber reinforced Polymer (AFRP), Basalt Fiber Reinforced Polymer (BFRP), Carbon Fiber Reinforced Polymer (CFRP) as well as Glass Fiber Reinforced Polymer (GFRP).

3.1 Load deflection

Load deflection graph of Control and Hybrid RC beams with two series that were Finite Element modelling using Atena Engineering 2D software and Experimental data, were drawn. The data had obtained from finite element modelling during analysed the result in Atena Engineering 2D software and experimental data, had obtained from previous laboratory testing for every types of Control and Hybrid beams.The comparison of Load deflection graph of finite element modelling and experimental data to obtained the validation between both methods for Control and Hybrid RC beams. Based on Figure 10 until Figure 17, shown the graph of Finite element modelling was placed linearly and reached 60.65kN for BS Control beam, 54.18kN for BG control beam, 41.79kN for BH-1 hybrid beam, 71.79kN for BH-2 hybrid beam, 47.88kN for BH-3 hybrid beam, 90.01kN for BH-4 hybrid beam, 39.18kN for BH-5 hybrid beam and 93.42kN for BH-6 hybrid beam of maximum flexural load value, while for experimental data was placed linearly also and reached 59.25kN for BS Control beam, 55.75kN for BG control beam, 42.50kN for BH-1 hybrid beam, 74.00kN for BH-2 hybrid beam, 46.50kN for BH-3 hybrid beam, 90.00kN for BH-4 hybrid beam, 38.50kN for BH-5 hybrid beam and 92.75kN for BH-6 hybrid beam maximum flexural load value and the percentage validation was 2.3% for BS control beam, 2.8% for BG control beam, 2.2% for BH-1 hybrid beam ,2.7% for BH-2 hybrid beam, 2.8% for BH-3 hybrid beam,0.01 for BH-4 hybrid beam , 1.7% for BH-5 hybrid beam ,0.7% for BH-6 control beam.The validation was effecting by mesh element chose which is 0.08m for BS control beam, 0.05m for BG Control beam, 0.07m for BH-1 hybrid beam, 0.0701m for BH-2 hybrid beam, 0.04m for BH-3 hybrid beam, 0.08m for BH-4 hybrid beam, 0.03m for BH-5 hybrid beam and 0.08m fro BH-6 hybrid beam for steel plate and concrete with material properties 0.2m of thickness and geometrically nonlinear [6]. Besides that, the coefficient multiplier of monitoring points was changing for load and for deflection of every types of Control and hybrid RC beam that were made the adjustment on the value of deflection and load until got the best graph of validation for finite element modelling in Atena Engineering 2D software and compared to experimental data. For the ultimate concrete strain were -0.0029 for BS Control Beam, -0.0029 for BG Control Beam, -0.0031 for BH-1 hybrid beam, -0.0032 for BH-2 hybrid beam, -0.0028 for BH-3 hybrid beam, -0.0031 for BH-4 hybrid beam, -0.0028 for BH-5 hybrid beam and -0.0028 for BH-6 hybrid beam.

Steel reinforcement bar had high modulus of elasticity, tensile strength, stiffness, but had low of durability thought the corrosion [3]. Either, the maximum flexural load value BG Control beam was lower that BS Control beam that because it had low modulus of elasticity ,strength and stiffness, but had high of durability thought the corrosion [2]. Futhermore, the hybrid combination of steel and GFRP reinforcement bars was suitable because it depend on its other, but GFRP bar could not increase the flexural strength on the beam if using similar or a little higher only from Steel bar that was because GFRP had low of modulus of elasticity but high of durability through corrosion [2]. However, bonded by least amounts of stirrups was decrease the stiffness, ductility, toughness and the flexural strength of the RC beams. However, bonded by increasing the amounts of stirrups had made the increment on stiffness, ductility as well as the flexural strength of the RC beam. By increase reinforcement ratio of GFRP and maintain steel reinforcement ratio, it was increase a little bit of flexural strength on the BH-3 hybrid beam because GFRP still had low of modulus of elasticity but high of durability through corrosion [2]. By increasing reinforcement ratio for both of GFRP and steel bars, it was increase the flexural strength on the BH-5 hybrid beam because GFRP still had low of modulus of elasticity but Steel bar had high modulus of elasticity [2]. However. by increasing reinforcement ratio for both of GFRP and steel bar, it was increase the flexural strength on the BH-6 hybrid beam because GFRP still had low of modulus of elasticity but Steel bar had high modulus of elasticity [2]. However, by increment amounts of stirrups was because the durability of the Hybrid RC beam could stand high flexural strength because of high bonding between the reinforcement and cause high stiffness, toughness, ductility of the BH-6 hybrid beam [2].

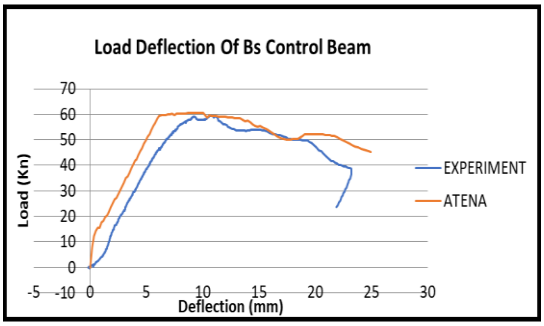

Figure 10: Graph of Load deflection of BS Control Beam from Atena Engineering Software and Experimental data

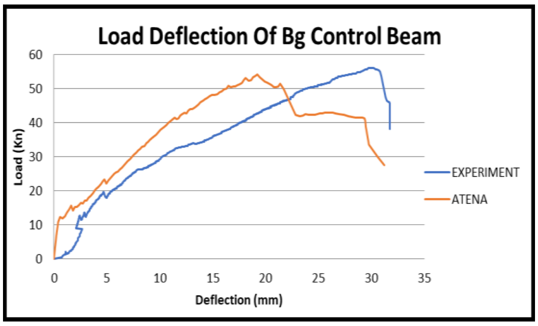

Figure 11: Graph of Load deflection of BS Control Beam from Atena Engineering Software and Experimental data

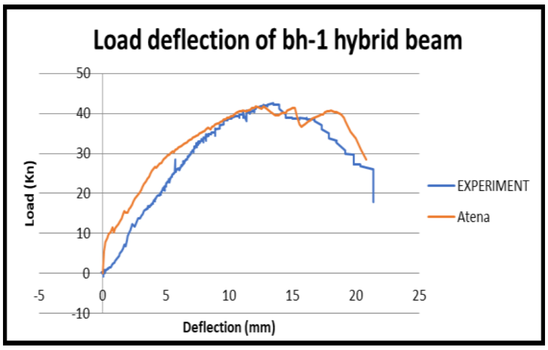

Figure 12: Graph of Load deflection of BH-1 Hybrid Beam from Atena Engineering Software and Experimental data

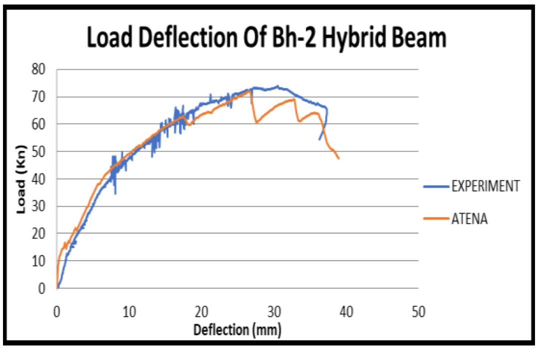

Figure 13: Graph of Load deflection of BH-2 Hybrid Beam from Atena Engineering Software and Experimental data

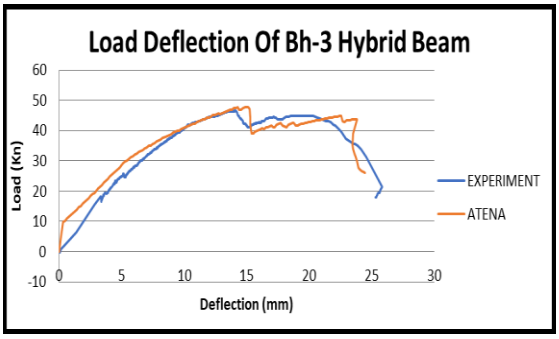

Figure 14: Graph of Load deflection of BH-1 Hybrid Beam from Atena Engineering Software and Experimental data

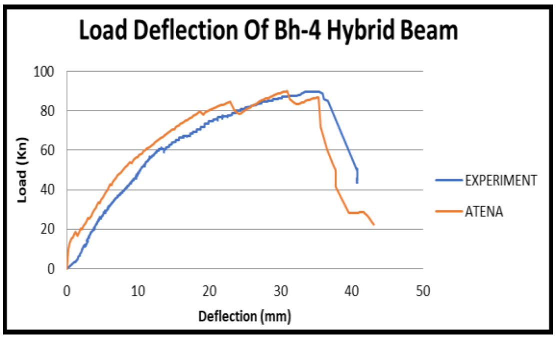

Figure 15: Graph of Load deflection of BH-4 Hybrid Beam from Atena Engineering Software and Experimental data

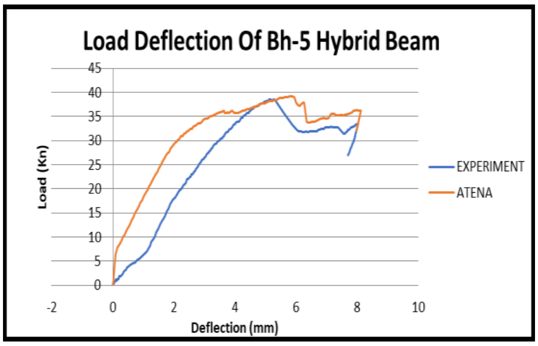

Figure 16: Graph of Load deflection of BH-5 Hybrid Beam from Atena Engineering Software and Experimental data

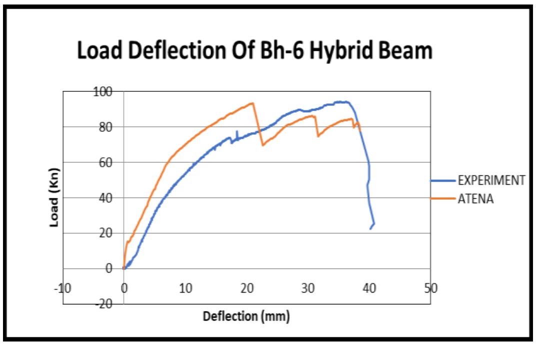

Figure 17: Graph of Load deflection of BH-6 Hybrid Beam from Atena Engineering Software and Experimental data

3.2 Crack pattern

From finite element modelling in Atena Engineering Software, a series of data had been tabulate to simplify the crack patterns to identify type of mode failure and differentiate data of each beam. All of the data that has been shown in Table 4 Crack Patternsof finite element modeling by using Atena Engineering Software. Based on the Table 4, they have two types of failure mode occurred on the RC beam which is Flexural failure for all types of Contol and Hybrid RC beams while Shear failure such as BG, BH-2, BH-3 and BH-5.

Table 4: Crack Pattern of Finite Element modelling by using Atena Engineering Software

Beam	Mesh Size Element (Mm)	Experimental For Half Of Beam Max Load (Kn)	Atena Engineering Software For Half Of Beam Max Load (Kn)	Atena Engineering Software For Half Of Beam Max Crack Width (Mm)	Mode Failure
BS	80.00	59.35	60.65	6.33	Flexural
BG	70.00	55.75	53.07	14.62	Shear and Flexural
BH-1	70.00	42.75	41.79	14.84	Flexural
BH-2	70.10	74.00	72.00	3.208	Shear and Flexural
BH-3	40.00	46.50	47.88	15.43	Shear and Flexural
BH-4	80.00	90.00	90.01	7.476	Flexural
BH-5	30.00	38.50	39.18	1.216	Shear and

					Flexural
BH-6	80.00	92.75	93.42	11.27	Flexural

When tensile stress highest than tensile strength of Control and Hybrid RC beams, the failure will occurred. Besides that, the increment of load may increase the crack depth on the Control and Hybrid RC beams. Crack spread at an angle from the original crack when applied load continuously. From finite element modelling of Control and Hybrid RC beams in Atena Engineering Software, a series of data had been tabulate to simplify the crack patterns to identify type of mode failure and differentiate data of each type of Control and Hybrid RC beams. All of the data that were shows in Table 4 Crack Patterns of Finite Element Modelling in Atena Engineering 2D Software.The finite element modelling of Atena Engineering software was shows that BH-6 hybrid beam had high flexural strength, high stiffness, durability through corrosion, ductility as well as high durability that had compared to other types of RC beams with 93.42kN maximum flexural load value. The result was because it had high of GFRP and Steel reinforcement ratio. As a result , from Table 4, when the failure occurred at the middle of the beam, the failure mode produces was flexural failure mode while crack pattern had occurred at supports of BG control beam, BH-2 hybrid beam, BH-3 hybrid beam and BH-5 hybrid beam that was because the shear failure also produced on that types of RC beams. Shear Failure obtained because of not enough amounts of stirrups by bonded the concrete and reinforcement on control and hybrid beam and it also because had low amount of maximum flexural load for the RC beams. When the result shown the maximum crack width produced exactly at the highest stress area that applied on the Control and Hybrid RC beams [2]. The amount of crack pattern were depend on the size of mesh element, when the mesh element larged, the crack pattern will occurs a little. Based on Table 4, mesh element of every types of RC beams was different which is 0.08m for BS control beam, 0.07m for BG control beam, 0.07m for BH-1 hybrid beam, 0.071m for BH-2 hybrid beam, 0.04m for BH-3 hybrid beam, 0.08m for BH-4 hybrid beam, 0.03m for BH-5 hybrid beam and 0.08m for BH-6 hybrid beam. In addition the width of cracked occurred depends on ultimate load of the control and hybrid RC beams, when the maximum load was high, the size of crack pattern was larged. Based on Figure 18, the example of flexural failure mode which is BH-6 Hybrid Beam when the crack pattern shown at the middle of beam and Figure 19 shown the example of shear and flexural failure mode which is BH-5 Hybrid Beam when the crack pattern beam failed at a support.

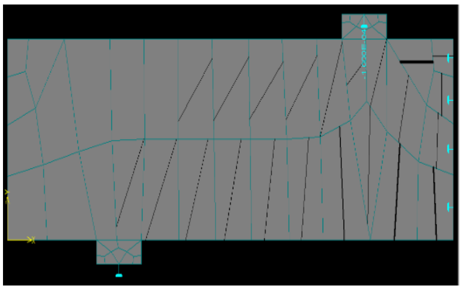

Figure 18: BH-6 Hybrid beam crack pattern with in Flexural failure mode

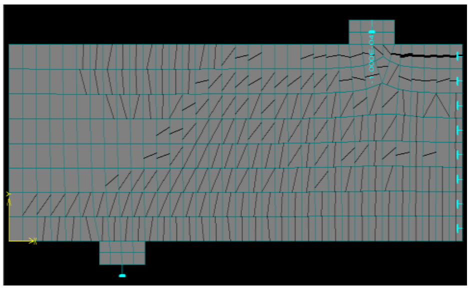

Figure 19: BH-5 Hybrid beam crack pattern with in Shear and Flexural failure mode

3.3 Load Deflection Parametric

Load deflection parametric were produced to investigate the effect of materials properties between four types of FRP which is BFRP, AFRP, CFRP and GFRP for all types of RC beam such as FRP control beam (BC,BG,BA,BB), BH-1, BH-2, BH-3, BH-4, BH-5 and BH6. Based on Table 4, it shown the maximum load between four types of FRP bars for every types of beam that were obtained from the Finite element analysis for CFRP,GFRP,AFRP as well as BFRP. Figure 20, the graph shown the CFRP for control beam was the highest maximum load obtained which is 111.8kN, followed by AFRP which is 61.68kN was more than 53.07kN of GFRP and for the lowest one was BFRP which is 48.29kN. Besides, From Figure 21 shown the comparison of FRP in BH-1 Hybrid beam, the result shown the maximum load in sequence from highest flexural strength was 64.1kN for CFRP. 52.56kN for AFRP was highert than 44.31kN of BFRP, 41.79kN of GFRP. AFRP was the highest deflection compared to CFRP, GFRP as well as BFRP before the beam became failure. Based on the result, the deflection forced of AFRP was high that had caused the BH-1 beam take a long duration of time to failure. Then, Figure 22, the graph shown that BH-2 produced 113.2kN the highest maximum load for CFRP, followed by AFRP with value 72.35kN, and the lower than AFRP was GFRP which is 71.97kN and the lowest one was BFRP with value 69.03kN. Based on the result, the deflection forced of GFRP was high that had caused the BH-2 beam taking a highest duration of time to reach the failure mode.

In addition, based on graph in Figure 23 shown that for the BH-3, CFRP obtained the highest maximum load which is 63.73kN, followed by BFRP which is 53.3kN and the third one was AFRP which is 52.7kN and for the lowest one was GFRP which is 47.88kN. BFRP was the highest deflection compared to CFRP, GFRP as well as AFRP before the beam became failure. Then, based on Figure 24 the graph shown the result of highest maximum load for BH-4 with the value 134.0kN which is CFRP and followed by AFRP which is 99.81Kn and the third one which is BFRP with value 96.44kN and the lowest one was GFRP which is 90.01kN. Based on the result, the deflection forced of BFRP was high that had caused the BH-4 hybrid beam take a highest time to failure. Besides that, Figure 19, the graph shown the highest maximum load for BH-5 was CFRP which is 39.47kN, followed by GFRP which is 39.18kN and the third one was BFRP which is 39.07kN and the lowest one was AFRP which is 39.05kN. The highest deflection was BFRP compare to CFRP, GFRP as well as AFRP before the beam became failure.Lastly, based on the graph from Figure 25, the highest maximum load for BH-6 still CGFP which is 122.4kN and followed by AFRP which is 101.1kN, the third one is GFRP which is 93.42kN and the lowest one is BFRP which is 92.37kN. Based on the result, the deflection forced of BFRP was high that had caused the BH-6 Hybrid beam take a highest duration of time before reached the failure mode. . Other than that, CFRP was produced the highest maximum flexural load that was because it has CFRP had providing the highest contribution of all types of FRP bars such as it had highest stiffness, highest flexural strength, high ductility as well as highest toughness. However, BFRP was the highest time to reach the failure [8].

Table 4: Maximum Load of FRP bars of finite element modelling by using Atena Engineering Software

Beam	Maximum load of FRP bars (kN)			
	GFRP	CFRP	AFRP	BFRP
FRP Control beam	53.07	111.80	61.68	48.29
BH-1	41.79	64.10	52.56	44.31
BH-2	71.97	113.2	72.35	69.03
BH-3	47.88	63.73	52.70	53.30
BH-4	90.01	134.0	99.81	96.44
BH-5	39.18	39.47	39.05	39.07
BH-6	93.42	122.4	101.1	92.37

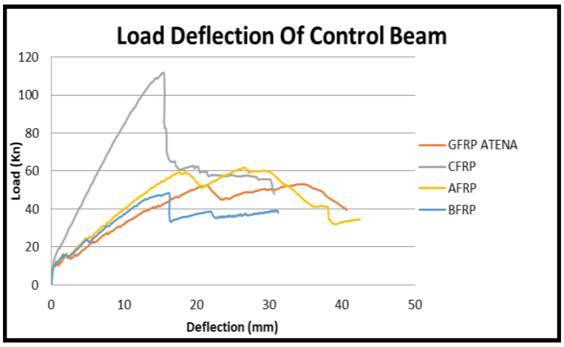

Figure 20: Load deflection graph for Control Beam

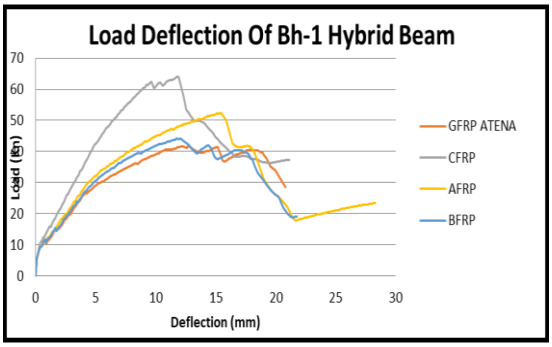

Figure 21: Load deflection graph for BH-1 Hybrid

Beam

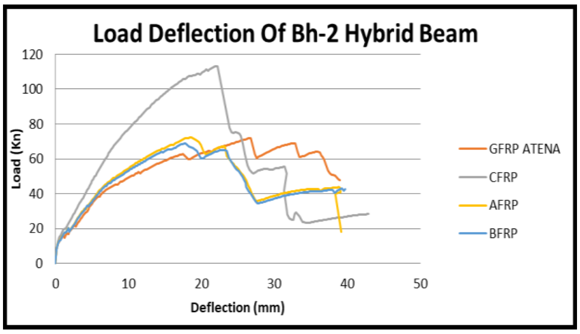

Figure 22: Load deflection graph for BH-2 Hybrid Beam

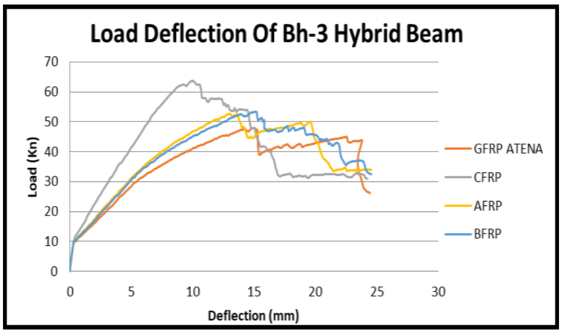

Figure 23: Load deflection graph for BH-3 Hybrid Beam

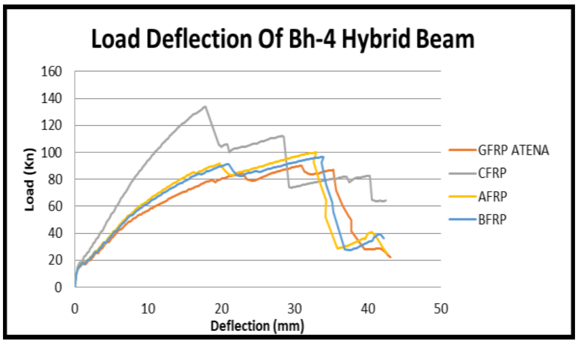

Figure 24: Load deflection graph for BH-4 Hybrid Beam

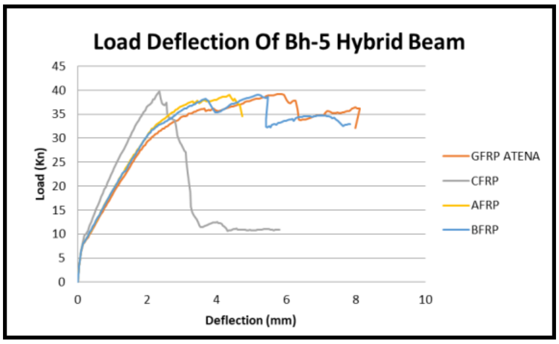

Figure 24: Load deflection graph for BH-5 Hybrid Beam

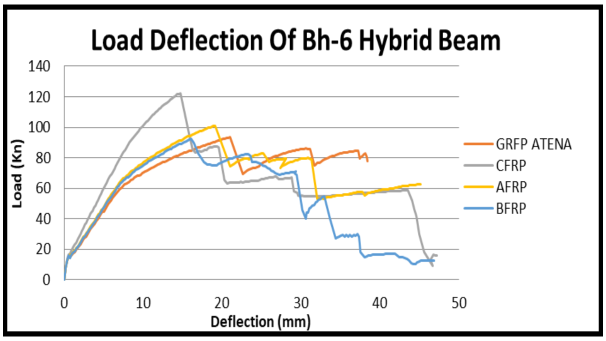

Figure 25: Load deflection graph for BH-6 Hybrid Beam

4. Conclusion

The main objective in this study is to develop a finite element modelling that can capture the effect of steel and GFRP hybrid reinforcement the flexural capacity on the flexural capacity of reinforced concrete beam, the result proved that, by the combination of steel and GFRP reinforcement bar and the suitable of stirrup spacing could increase the flexural capacity of the beam such as 71.79kN for BH-2, 90.01kN for BH-4 as well as 93.42kN for BH-6, it more than BS which is 60.65kN. The second objective is to validate the finite element modeling by using Atena Engineering Software with the experimental data, as a result, the comparison and validating results for modal analysis and previous laboratory measurement were less 10%; 2.1% for BS Control Beam, 4.8% for BG Control Beam, 2.2% for BH-1 Hybrid Beam, 2.7% for BH-2 Hybrid Beam, 2.9% for BH-3 Hybrid Beam, 0.01% for BH-4 Hybrid Beam, 1.7% for BH-5 Hybrid Beam and also, 0.7% for BH-6 Hybrid Beam. Therefore, it can be determined as the acceptable analysis for modelling work and previous laboratory measurement and for the last objective is to analysis the effect of materials properties of the Four types of FRP bar which is BFRP, CFRP, AFRP and GFRP, based on the result between all type of RC beam, it shown that the CFRP was the highest flexural strength because it could stand the highest load for all types of RC beam which is 111.8kN for CFRP control beam(BC), 64.1kN for BH-1, 113.2 for BH-2, 63.73 for BH-3, 134.0kN for BH-4, 39.47kN for BH-5 and 122.4kN for BH-6, all the result shown highest than all types of FRP which is AFRP, BFRP as well as GFRP that was because of the materials properties of CFRP.

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