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Compressive Strength of Concrete Retrofitted by Fiberglass - Reinforced Polyethylene Terephthalate EthyleneVinyl Acetate with varying thickness

Guillermo O. Bernabe[1a], Orlean G. dela Cruz[1b], Joseph Raniel A. Bianes[2]
[1a, 2]Faculty of Department of Civil Engineering, College of Engineering
[1b]Faculty of Department of Engineering Science, College of Engineering
Polytechnic University of the Philippines - Manila

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Abstract:
One of the issues presently experienced by the construction and construction sectors is the deterioration of the quality of multiple types of concrete constructions. Strengthening of these structures becomes necessary whenever the reinforced concrete is insufficient to maintain their service functions and/or due to natural causes. This research study aimed to analyze the effect of varying thickness of fiberglass enhanced (PET-EVA) on compressive strength of concrete for retrofitting. The experimental research method was employed in this study using ASTM C39/C39M for compressive strength of concrete. Fiberglass retrofitted concrete specimens divided into three categories. They are (a) chopped strand mat, (b) chopped strand mat and mesh and (c) chopped strand mat, mesh with PET-EVA. The average compressive strength of retrofitted concrete specimens with 1, 3, and 5 layers were 14.993 MPa, 22.280 MPa, and 20.557 MPa, respectively. The compressive strength for specimens 1, 3, and 5 were 305.239 kN, 482.193 kN, and 472.101 kN, respectively. The researchers concluded that the compressive strength of all layers of the concrete fiberglass-reinforced PET-EVA passed the minimum requirements as prescribed by the ACI Standards.

Keywords:*compressive strength, fiber-reinforced PET-EVA, ultimate load capacity, and concrete retrofitting*

I. INTRODUCTION

Throughout the 20th century, numbers of structures in the field of civil engineering has significantly increased. These structures are built for different purposes with different materials as per to its design requirement. Structures are being used to various activities and subjected to varying types of loads, whether it's human-made or geophysical. Once these loads are subjected to the structures and exceed its capacity and strength, it will cause minor damages or even significant damages to the structure itself. When the loss is minor, the structure can undergo retrofitting.

Retrofitting predominantly concerned with structural improvement, enhancing and increasing the strength to decrease the number of hazards in the utility time of the structures.

Strengthening of these structures becomes necessary whenever the flexural or shear strength of reinforced concrete is insufficient to maintain their service functions. Repairing and rehabilitating structures in distress after a significant lifespan or damage due to causes is cost-effective. Different methods and techniques were developed over centuries to have a solution to this kind of problem. "Construction elements, mainly non constructional ones, like facade, panels, piping for sanitation, decorative, non-recoverable form work and other products" [1]. GFRP helps the structural integrity of reinforced concrete members like beam in a method

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of wrapping GFRP or bond externally to a structural member.

II. Review of Related Literature

R. Vaghei et al. (2013) state that there are different situations in which structures would require strengthening or rehabilitation due to the lack of stiffness, strength and durability. One of the most common cases where a structure needs strengthening during its lifetime is a seismic retrofit to satisfy current code necessities.

"However, limited testing has been done on precast walls and their connections, many precast wall connection designs are mainly based on theory that does not adequately model the complex interaction between the concrete and connection material. These connections have been proved to be brittle and because of their low strength, do not sufficiently absorb earthquake energy. Additionally, steel connectors are subject to extreme levels of corrosion where this corrosion results in significantly decreased strength. Therefore, a reliable connection is need for new and retrofit connection that will absorb earthquake energy and last the life of the structure" [2][3].

"In recent years, fiber reinforced polymer (FRP) composites have found increasingly wide applications in civil engineering, both in the retrofit of the existing structures and in new construction. FRP composites consist of fibers embedded polymeric resins and possess several advantages over steel, including their high strength-to-weight ratio and excellent corrosion resistance. As a result, the use of FRP composites as externally bonded reinforcement for the retrofit of structures has become very popular in recent years" [4][5][6].

"The confinement in the form of GFRP sheets increases the compressive strength of the specimens remarkably" [7][8].

"If the specimen is wrapped with 8 layers of GFRP sheets the strength increases to 47% of the strength without confinement. From the study it can be concluded that the column can be confined with GFRP sheets to increase their strength to a great extent. This material (GFRP) may be used in seismic retrofitting or RCC compression members" [7][8].

"The ultimate load carrying capacity of all the beams along with the nature of failure and deflections along with the percentage increase in strength as an effect of strengthening, are summarized and the deflection – deformability indices and ductility along with FRP reinforcement ratio are all summarized" [9][10].

"The resistance of abaca fiber reinforced polypropylene composites against dry wood termites was dependent on a number of factors. The effects of these factors either working alone or in combination with other factors must be considered in the determination of the optimum formulation for the composites" [11].

According to the study of Jayvee Gagan and Dr. Bernardo Lejano that the parameters GMS and water cement ratio have the significant individual effect on the properties of concrete. Though Pig Hair Fiber alone doesn't have significant effect on the response, its interaction with other parameters exhibited significance. Regardless of whether the concrete has some additional materials incorporated into it, the relationship between its water cement ratio and compressive strength remains to be inversely proportional.

Retrofitting is a common practice in structural works and can be achieved by a variety of ways. Past studies proved that the application of FRP materials in particular is considered to be the most widely used because of its convenience and has higher workability than any other methods. Our current study signifies the structural performance of PET-EVA as an alternate FRP to be used. The composite material PET-EVA blend shows promising properties as a retrofitting material due to its ability to resist stress and durability. To use PET-EVA it is combined with fiberglass to take advantage of its structural capabilities. The composite material consists of fiberglass mats, mesh and PET-EVA blend together with fire retardant clear cast polyester resin to test its compatibility and produce a retrofitting material that is available and cost-efficient.

III. Research Methodology

The study entitles Compressive Strength of Concrete Retrofitted by Fiberglass-Reinforced Polyethylene Terephthalate EthyleneVinyl Acetate with varying thickness employs the experimental research as its study design.

"Experimental Research is a systematic, rigorous investigation of a situation or problem in order to generate new knowledge or validate existing knowledge (Liaomanie, 2002)".

In relation thereby, different studies and experimentation showed the Fiberglass reinforced polymer materials possess less brittleness. However, the researchers hypothesize that incorporating Polyethylene Terephthalate- Ethylene Vinyl Acetate (PET-EVA) blend to Fiberglass reinforced polymer will increase the ductility of the system, hence, improving its susceptibility to various brittle failures.

Concrete Mixture

A total of 9 concrete cylinders, 6in x12in dimension, is to be made using the Class A design mix and to be cured for 28 days.

The curing method will be patterned in accordance to ASTM C192 Standard Practice for making and Curing Concrete Test Specimens in the Laboratory. All of these samples will be subjected to compression test according to ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. Three (3) of these samples will be retrofitted with Fiberglass chopped strand mat only, three (3) will be retrofitted with Fiberglass chopped strand mat and Fiberglass mesh, and the last three (3) will be retrofitted with Fiberglass chopped strand mat, Fiberglass mesh and PET-EVA.

The mixing of concrete is done in the Bureau of Research and Standards. American Concrete Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70 percent of the specified compressive strength. Since the type of cement used in this study falls under ASTM C 150 Type I cement which has a minimum of 7 days curing to reach the 70% of the specified compressive strength, the concrete cylinders were prepared and cured for 28 days. Then these cylinders are removed from the curing tank and the compressive strength (f'c) of the cylinder samples that were retrofitted are tested.

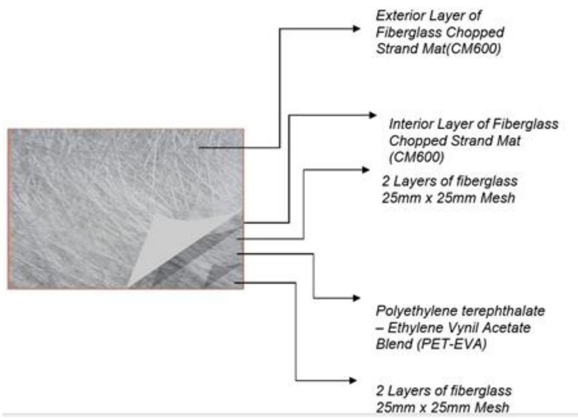

Figure 1. Schematic Representation of Layers' Composition

Figure 1 shows the Schematic representation of layers' composition of the retrofitting material. The outermost exterior layer is the fiberglass chopped strand mat (CM 600) followed by interior layer of Fiberglass chopped strand mat (CM 600) then the 2 layers of fiberglass 25mm x 25mm Mesh and the polyethylene terephthalate – Ethylene Vinyl Acetate Blend (PET-EVA) and finally the innermost layer is the two layers of Fiberglass 25mm x 25mm Mesh.

IV. Results and Discussions

The study was conducted to analyze the effect of varying thickness of fiberglass reinforced PET-EVA on compressive strength of concrete for retrofitting. Three (3) of these samples will be retrofitted with fiber glass chopped strand mat only, other three (3) will be retrofitted with Fiber Glass Chopped Strand Mat and Fiberglass Mesh, other three (3) will be retrofitted with Fiber Glass Chopped Strand Mat, Fiberglass Mesh and PET-EVA making it a total of nine (9) samples. Within the process, the researcher

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made sure that the objective of the study was kept at hand to acquire pertinent and reliable data.

Weight of the material is being taken into consideration as to be considered as well in design process. It is necessary for a designer to determine the contributed or added effect of the material to adjust or factor the load which is essential in determination of the allowable capacity of the material being tested.

Table 1. Concrete weightof specimen a (LAYER 1 – 4.3mm thickness)

Specimen	Actual Diameter (mm)	Weight (kgs)
1	161	12.729
2	161	12.372
3	161	12.422
Ave	**161**	**12.508**

Table 1 presents the difference in weight of specimens for Layer 1. Three (3) samples with 161 mm diameter is having an average weight of 12.508 kilograms.

Table 2. Concrete weight of specimen b (LAYER 2 – 6.8mm thickness)

Specimen	Actual Diameter (mm)	Weight (kgs)
1	166	13.795
2	166	13.792
3	166	13.718
Ave	**166**	**13.768**

Table 2 presents the difference in weight of specimens for Layer 3. Three (3) samples with 166 mm diameter is having an average weight 13.768 kilograms. Moreover, data exposes as well that specimen B is 6.551% heavier than specimen A.

Table 3. Concrete weight of specimen c (LAYER 3 – 9.3 mm thickness)

Specimen	Actual Diameter (mm)	Weight (kgs)
1	171	14.257
2	171	13.802
3	171	14.215
Ave	**171**	**14.061**

Table 3 presents the difference in weight of specimens for Layer 5. Three (3) samples with 166 mm diameter is having an average weight 14.601 kilograms. Furthermore, it reveals that there is a 12.416% increase in weight compared to specimen A and, 2.315% higher that of specimen B.

Table 4. Average compressive strength of three (3) specimens / layers

Specimen	Applied Load (kN)	Compressive Strength (MPa)
A	305.239±31.42	14.993±1.58
B	482.193±109.94	22.280±5.08
C	472.101±56.65	20.557±2.46

Table 4 shows the analysis, computations, tabulations, and computations of gathered data; some noteworthy findings arose. These findings at this moment presented.

1. The compressive strength of concrete retrofitted by system of fiberglass reinforced PET-EVA with system composed of:
   a. Layer 1 having approximately of 4.3mm thick is with average compressive strength of 14.993±1.58MPa.
   b. Layer 3 having approximately 6.8mm thick is with average compressive strength of 22.280±5.08MPa.
   c. Layer 5 having approximately 9.3mm thick is with average compressive strength of 20.557±2.46MPa.

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2. The ultimate load capacity that a Fiberglass reinforced PET-EVA can carry in terms of Compressive Strength with:
   a. Layer 1 having approximately 4.3mm thick is with average compressive strength of 305.239±31.42 kN.
   b. Layer 3 having approximately 6.8mm thick is with average compressive strength of 482.193±109.94 kN.
   c. Layer 5 having approximately 9.3mm thick is with average compressive strength of 472.101±56.65 kN.

V. CONCLUSION

The compressive strength of all Fiberglass reinforced PET-EVA passed the minimum requirements prescribed by the American Concrete Institute (ACI) of 13.79Mpa. It is noticeable that layer 3 has the most significant average ultimate load capacity among the three specimens. Furthermore, it is the most effective retrofitting system in this experiment.

The researchers recommend future researchers to:

1. Increase the time allotted in drying up the retrofitting system.
2. Conduct a comparative study on the difference in cost between all the retrofitting materials already available in the market and the retrofitting system with 3 layers (approximately 6.8mm thickness) to find out if it is economical.
3. Lastly, conduct a research on the most effective and efficient number of layers or thickness of retrofitting system of Fiberglass reinforced PET-EVA.

VI. REFERENCES

[1] J. D. Chaitanya, G. V. S. Abhilash, P. K. Khan, G. Manikanta, and V. Taraka, “Experimental Studies on Glass Fiber Concrete American Journal of Engineering Research (AJER),” no. 5, pp. 100–104, 2016.
[2] W. Paul, “CONNECTION OF PRECAST SHEAR WALL PANELS USING CARBON FIBER COMPOSITES,” no. May, 2000.
[3] P. W. Mcmullin, A. M. Asce, C. P. Pantelides, M. Asce, L. D. Reaveley, and M. Asce, “CFRP Composite Connector for Concrete Members,” no. February, pp. 73–82, 2003.
[4] J. G. T. T. Y. Y. L. Wong and S. L. Dong, “INNOVATIVE FRP-STEEL-CONCRETE HYBRID COLUMNS,” vol. I, pp. 545–554, 2005.
[5] J. G. Teng, “Hybrid FRP – concrete – steel tubular columns : Concept and behavior,” vol. 21, pp. 846–854, 2007.
[6] Y. Tao and R. A. M, “International Journal of Mining Science and Technology Novel hybrid FRP tubular columns for sustainable mining infrastructure : Recent research at University of Wollongong,” Int. J. Min. Sci. Technol., vol. 24, no. 3, pp. 311–316, 2014.
[7] M. K. Tiwari, R. Chandak, and R. K. Yadav, “S t r e n g t h e n i n g o f r e i n f o r c e d c o n c r e t e r e c t a n g u l a r c o l u m n u s i n g f i b e r r e i n f o r c e d p o l y m e r i c m a t e r i a l a s l a t e r a l c o n f i n e m e n t . Abstract :,” vol. 2, no. 4, pp. 913–919, 2014.
[8] S. Tiwari, S. Dubey, and Y. K. Bajpai, “Enhancing the Compressive Strength of Square Cross Sectional Column Using FRP Material,” vol. 5, no. Xi, pp. 2827–2832, 2017.
[9] T. Sen and H. N. J. Reddy, “Strengthening of RC beams in flexure using natural jute fibre textile reinforced composite system and its comparative study with CFRP and GFRP strengthening systems,” Int. J. Sustain. Built Environ., vol. 2, no. 1, pp. 41–55, 2014.
[10]T. Sen and H. N. J. Reddy, “Flexural strengthening of RC beams using natural sisal and artificial carbon and glass fabric reinforced composite system,” Sustain. Cities Soc., 2013.
[11]R. D. Manalo and C. M. Garcia, “Resistance of Abaca Fiber-Reinforced Polypropylene Composites AgainstDrywood Termites.”

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