Study on Fly Ash Based Interlocking Concrete Paver Block Using Chopped Fibers

Cong Bang TRUONG*  
Mien Tay Construction University, 20B Pho Co Dieu street, Vinh Long, Vietnam  
* Corresponding author: bangmtvl@gmail.com

Abstract. In modern days concrete paver block turned in to a component of towns and urban areas. It is to be locating in residential, commercial and industrial areas like as shopping malls, parking areas, footpaths, transport stops etc. The aim of this paper is to construct paver block by using cement is replaced by different percentages of fly ash and various types of fibers. There are the motive behind using of fly ash in concrete to improve the durability and strength of harden concrete and fly ash also cost effective. In this paper also discussed about the various types of chopped fibers which used in paver blocks like nylon fiber, steel fiber, coconuts fibers, glass fibers, polypropylene fibers etc for improving strength of paver blocks. The other materials have composed to design paver blocks, fine aggregate and coarse aggregate for concrete mixture. The curing process of paver block has done for 7 days, 14 days and 28 days. After curing days it is tested for compressive strength.

Keywords: Chopped fibers, Compressive strength, Fly ash, Aggregates, Paver blocks, Curing process.

1. Introduction
Interlocking concrete paver block have been using in the World a decade ago. For most necessity of paver-block in footpaths and parking zones, but now day’s broadly apart uses where the construction of pavement using hot bituminous mix or cement concrete technology is not possible or advantageous. Concrete block is used now alternative pavement to asphalt and concrete pavements. Now these present times there has been investigating the characteristics of various fibers using in paver block to increases strength, durability and reduction in cracks. Advantages of paver block are low maintenance and cost effective. The recent experimental studies about fiber using in paver block found that “the compressive strength and flexural strength increased. For this benefit it can be used in heavy traffic area and give surface resistance for long life”. By using of fiber to design paver block that give the best result to improve the quality of constructions and like pelting asphalt and concrete not cheaply crack and break use of fiber.

As concrete is second most consumed commodity in the world which generates a large amount of carbon dioxide and is responsible for global warming. Huge production of conventional concrete for infrastructural development also leads to probability of difficulties of getting raw materials in future. So, research is going on for sustainable material for green concrete. Study shows that replacing cement partially or fully can be a ecofriendly approach which also reduces carbon emission, caused due to cement production. Concrete can be produced by replacing concrete with fly ash [1-2], red mud [3], silica fume [4-5], rice husk, metakaolin, blast furnace slag. Geo-polymer masonry can be a sustainable...
building material which is produced by complete elimination of cement or partial replacement of cement with industrial wastes like fly ash, blast furnace slag as binders [6-12].

Mass reduction of GPC block with quarry dust at the end of 84 days is found to be 0.72% due to hydrochloric acid resistance [13]. Fly ash combines with alkalis from cement that might otherwise combine with silica from aggregates, prevents destructive expansion, hence durability increases [14]. Addition of fibers may be natural [6][13] [15-16] or synthetic [1] [17-22], in designed concrete generally not much have effect on compressive strength but flexural strength increases [6].

2. Materials and methods

There were discussed about methodology of different fibers below mentioned with required methods:

To design the paver block with different types of fibers the usual materials used like fine – aggregate of 20mm size, coarse aggregate, cement, fly ash and water. The additional materials like semi grit less than 9.5mm particle, dolomite powder, pigment and quarry dust having size less than 4.75mm was used in coconut fiber paver block. At the content of glass fiber the other materials have used like Sikament FF liquid as admixture used in concrete. In case of polypropylene fiber. Sodium hydroxide and Sodium silicate have used. In nylon fiber have no additional materials. [1][6][19][23]

COCONUT FIBER: Coconut fiber is a natural fiber, when it added to the concrete it increases the many properties of concrete like compressive strength, flexural strength, split tensile strength of concrete and also reduce the cracking. Coconut fibers are easily available with large amount and also very cheap. [6][14]

Fig 1. Coconut fiber

Table 1. Properties of coconut fiber

| Material Specification | Physical properties of Cement | Aggregates | Other Materials | properties of coconut fiber |
|------------------------|-------------------------------|------------|-----------------|-----------------------------|
|                        | Specific gravity              | 3.05       | 2.5             | 3.148 length 6 mm           |
|                        | Consistency limit             | 27%        | 2.93            | 4.266 Diameter 0.01mm       |
|                        | Initial setting time          | 45min      | 0.097%          | 2.84 to 2.86                |
|                        | Final setting time            | 4 hr45min  |                 |                             |

GLASS FIBER: Glass fiber is a material consists of various fine fibers of glass. The use of glass fiber in concrete is to improve flexural strength. Glass fiber can use replacement of standard steel
reinforcement in concrete. The advantages of Glass fibers to improve the matrix densification, reducing of voids, minimize cracking due to stresses and improve the durability to reinforcement corrosion [1][15][17].

![Glass fiber image](image1)

**Figure 2. Glass fiber**

**Table 2. Properties of Glass fiber**

| Material Specification | Physical properties of Cement | Chemical properties of fly ash | Aggregates | Physical properties of glass fiber |
|------------------------|-------------------------------|--------------------------------|------------|----------------------------------|
|                        | Specific gravity              | SiO<sub>2</sub>                   | Specific gravity | Diameter μm  |
|                        | 3.14                          | 61.24                           | 2.62        | 12                                |
|                        | Consistency limit             | Al<sub>2</sub>O<sub>3</sub>      | Specific gravity | Specific Gravity              |
|                        | 33%                           | 25.00                           | 2.66        | 2.60                              |
|                        | Initial setting time          | Fe<sub>2</sub>O<sub>3</sub>      | Fineness Modulus | Water absorption value |
|                        | 140 min.                      | 8.71                            | 3.034       | 0.45%                             |
|                        | Final setting time            | Na<sub>2</sub>O                 | Grading Zone II. | Impact Value |
|                        | 310 min.                      | 0.09                            | 26%         | 26%                               |
|                        |                               |                                 |             | Elasticity, (GPa)  |
|                        |                               |                                 |             | 80                                |
|                        |                               |                                 |             | Tensile Strength (GPa)  |
|                        |                               |                                 |             | 2.5                               |

![Nylon fiber image](image2)

**Figure 3. Nylon fiber**

NYLON FIBER: The melt – processed of nylon is nylon fiber. It is a Thermoplastic silky material. There is various products manufactured used of nylon fiber like rope, carpet, clothes, tires etc. The used of fiber in concrete improved the durability of concrete. The addition of nylon fiber with various
proportions in concrete, give the effects on compressive and tensile strengths and work-ability e.t.c. [19-20][24].

Table 3. Properties of Nylon fiber

| Material Specification | Aggregates | Physical properties of Nylon fiber |
|------------------------|------------|-----------------------------------|
| Specific gravity       | 3.15       | Specific gravity                  |
| Consistency limit      | 33%        | Fineness Modulus                  |
| Fineness Modulus       | 3.8        | % moisture                        |
| Density                | 1.15       | g/cm³                             |
| Water absorption       | 1.4%       | Melting Point                     |
| Melting Point          | 190-350°C  |                                   |

POLYPROPYLENE FIBER: Polypropylene is a thermoplastic polymer used in variety applications. It also known as polypropylene. Polypropylene is the best fiber for its better performance in industrial and construction field. The use of different proportion of fiber in concrete mix improve the compressive strength, splitting tensile strength and mechanical properties of concrete [7][23][25-35]

Table 4. Properties of Polypropylene fiber

| Material Specification | Aggregates | Physical properties of Polypropylene fiber |
|------------------------|------------|-------------------------------------------|
| Specific gravity       | 3.17       | Specific gravity                          |
| Consistency limit      | 37%        | class F                                   |
| Diameter               | 0.03-0.04mm| Cut length                                |
| Density                | 1.15       |                                           |
| Water absorption       | 1.4%       |                                           |
| Melting Point          | 190-350°C  |                                           |
| Initial/ Final setting time | Melting Point |
|---------------------------|--------------|
| 60 min./450 min           | 150-160°C    |

2.1. Mixing and casting the specimens

COCONUT FIBER: In the bottom layer of paver block the concrete contains cement, fine aggregates, quarry dust and in the top layer of paver block the materials used like mix of cement, semi grit, dolomite powder and fly ash. The 20mm coconut layer is to be added in top layer with the concrete proportion of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% depend on the weight of concrete. The wet purpose of water only added in the mix at casting time. After 24 hours the specimens placed to water curing process 7, 14, and 28 days. [6]

GLASS FIBER: The mix proportion of glass fiber paver block have designed M35 grade. At the start the percentage of glass fiber from 0.1% to 0.4% per the weight of cement added in mix and 10 to 40 percentage of fly ash added to the mix replacement of cement. The casting and testing procedure have done by two stages. In first stage the paver blocks are casted mix with glass fibre and placed to water for curing age of 7 and 28 days.

NYLON FIBER: There are two methods used for precast concrete.

1. Wet mix
2. Dry mix

In wet mix, concrete was compacted in the mould but in dry mix first the semi dry cohesive concrete mix then placed to mould but not immediately compacted. After compacted the concrete mix putout from the mould. In this theory M20 concrete mix used. Cement was replaced by fly ash with percentage of 10%, 20%, 30% and 40%.

POLYPROPYLENE FIBER: In this study the paver block was also designed. The crushed stone of granite used as coarse aggregate and quarry sand used as fine aggregate. Tap water was used for mixing and curing process. Fly ash was used replacement of cement and activator alkaline solutions were used replaced of water. Activator alkaline solution is specially used polymerization process. Polypropylene fibers were mixed in the concrete with different percentages from 0.1% to 0.5%.

2.2. Testing of the specimens

COCONUT FIBER: There were three types of tests compressive strength test, flexural strength test and water absorption test done in this study. For compressive strength compressive machine and for flexural strength universal testing machine was used. All tests determined. For every test three cubes were tested and from the result the average value was taken.

GLASS FIBER: The load was applied in compressive strength without flick and the load enhanced consecutively at a rate of 15 +/- 3N/mm2/min until the found of greater loads. in flexural strength test the load was applied without flick and load increased consecutively at a rate of 6 KN/min. In the first stage the results were observed with different percentages of glass fiber but in second stages the results were observed with different percentages of fly ash added with glass fiber.

NYLON FIBER: There was only compressive strength test was conducted in this study. After cured days the test was conducted. For test three cubes was taken and the average strength value was reported from the test result.

POLYPROPYLENE FIBER: Concrete specimens are under testing three times at 3,7 and 28days. Another three tests were abrasion resistance test was conducted at 28 days, flexural strength test at 28 days and water absorption test at 24 hours.

3. Results and Discussion
COCONUT FIBER: The compressive strength increased from 1.22% to 6.81% with the enhanced of fibers from 0.1% to 0.3% at the curing age of 28 days. The increased of flexural strength from 2.55% to 14.65% with added of fibers from 0.1% to 0.5% respectively. By the changing of top layer, thickness from 10 mm to 40mm the strength was increased successively.

GLASS FIBER: The addition of 0.2% optimal fiber by weight of cement and inclusion of glass fiber, the compressive strength of paver block increased. As the curing age of 28 days added 0.2% fiber, increased of compressive strength 10.52%. There was 90.31% cost decreased compare to the each unit of paver block. On the replacement of cement with 20% fly ash and addition of 0.2% glass fiber.

NYLON FIBER: After the completed compressive strength test, noticed that the strength was increased by the addition of 0.3% nylon fiber and 20% fly ash. The strength was increased during the curing age of 7, 14 and 28 days.

POLYPROPYLENE FIBER: It significant that the use of polypropylene fibers in geo-polymer concrete increased the flexural, abrasion resistance and compressive strength. The inclusion of 0.2% Polypropylene fiber in paver block the abrasion result at age of 28 days increased up to 45%. By the weight of 0.4% Polypropylene fiber was added to the geo-polymer concrete the flexural strength and compressive strength highly increased.

4. Conclusion
Study about inclusion of various types of fibers in concrete, shows that strength as well as durability increases. In addition to that fly ash, which was harmful to the environment if dumped openly, can be used as replacement of cement partially or fully. Fly ash in concrete enhances its strength, durability, mechanical properties. Hence the use of cement in concrete decreases which ultimately reduces cost, as well as carbon footprints of structure. So production of concrete for pavers with flyash and fibres is an economical sustainable approach.

5. References

[1] Kumar, BAV Ram, and J. Venkateswarao Rao. Effect of Inclusion of Glass Fibers and Fly ash in Concrete Paver Blocks. International Journal for Research in Applied Science & Engineering Technology, 3(9), 2015, 437 - 443.
[2] Patel, Vikas Kumar, and V. V. Singh. An Experimental Investigation on Precast Cement Concrete Paver Blocks Using Fly Ash. 2017.
[3] Nayak, Sipalin, Siba Prasad Mishra, and Nagarika Panda. Red Mud, the Cutting Edge of Self Compacting Cement Concrete. 2017.
[4] Jena, Sanghamita, Ramakanta Panigrahi, and Pooja Sahu. Mechanical and Durability Properties of Fly Ash Geopolymer Concrete with Silica Fume. Journal of The Institution of Engineers (India): Series A, 100(4), (2019), 697- 705.
[5] Jena, Sanghamita, Ramakanta Panigrahi, and Pooja Sahu. Effect of Silica Fume on the Properties of Fly Ash Geopolymer Concrete. Sustainable Construction and Building Materials. 2019, 145 - 153.
[6] Navya, G., and J. Venkateswarao Rao. Experimental investigation on properties concrete paver block with the inclusion of natural fibers. Ratio Li (2014): 0 - 08.
[7] Muduli, S. D., et al. Effect of NaOH concentration in manufacture of geopolymer fly ash building brick. Greener Journal of physical sciences, 3(6), (2013), 204 - 211.
[8] Radhakrishna, Venugopal K., V. Sasalatt, and T. Venumadhav. Study on geopolymer masonry as sustainable building material. J Environ Res Dev, 9(3), (2015), 925 - 932.
[9] Panda, Sagarika, Ramakanta Panigrahi, and M. L. Narshimam. A review on utilization of alkali activated flyash and ggbs as green concrete. Adalya Journal, (2019), 91 - 96.
[10] Jena, Sanghamita, and Ramakanta Panigrahi. Performance assessment of geopolymer concrete with partial replacement of ferrochrome slag as coarse aggregate. Construction and Building Materials, 220, (2019), 525 - 537.
[11] Jena, Sanghamitra, Ramakanta Panigrahi, and Anshuman Panda. Influence of GGBS on the Properties of Charge Chrome Based Geopolymer Concrete in Ambient Temperature. SSRN 3553996, (2020).

[12] Jena, Sanghamitra, and Ramakanta Panigrahi. Parametric study on sustainable geopolymer concrete. International Journal of Sustainable Materials and Structural Systems, 3(3), (2018), 218 - 234.

[13] Uday, V. Sai, and B. A. Jitha. Concrete Reinforced with Coconut Fibres. International Journal of Engineering Science and Computing, 7, (2017), 10436 - 10439.

[14] Ogunbode, Ezekiel B., et al. Microstructure and mechanical properties of green concrete composites containing coir fibre. Chemical Engineering Transactions, 61, (2017), 1879 - 1884.

[15] Subramani, T., and J. Karthick Rajan. Experimental Investigation Paver Block Natural Fiber, K.Vamshi Krishna and J. Venkateswara Rao, Effect of Glass Fibres In Rigid Pavement. International Journal Of Scientific Research And Education, 2(9), (2014), 1797 – 1804

[16] Kundu, Sarada Prasad, Sumit Chakraborty, and Subrata Chakraborty. Effectiveness of the surface modified jute fibre as fibre reinforcement in controlling the physical and mechanical properties of concrete paver blocks. Construction and Building Materials, 191, (2018), 554 - 563.

[17] Santhosh, Joel, and Ravikant Talluri. Manufacture of interlocking concrete paving blocks with fly ash and glass powder. Journal Impact Factor, 6.4 (2015), 55 - 64.

[18] Thakur, A., A. Saxena, and T. R. Arora. Effect of Partial Replacement of Cement by Fly Ash with Using Nylon Fiber in Concrete Paver Block. International Journal of Engineering Research & Technology, ISSN: 2278 - 0181.

[19] Kumar, Barun, et al. Evolution of Properties of Pavers Blocks Using Nylon Fiber Fly Ash and Rice Husk Ash for Medium Traffic.

[20] Khan, Mehran, and Majid Ali. Use of glass and nylon fibers in concrete for controlling early age micro cracking in bridge decks. Construction and Building Materials, 125, (2016), 800 - 808.

[21] Ganesan, Lavanya, and Chippymol James. Strength characteristics of Concrete Paver Blocks embedded with PET Fibres. Ratio, 158, 0 - 45.

[22] Caetano, Juliana Argente, Valdir Schalch, and Javier Mazariegos Pablos. Characterization and recycling of the fine fraction of automotive shredder residue (ASR) for concrete paving blocks production. Clean Technologies and Environmental Policy, (2020), 1 - 13.

[23] Rajesh, A. Ananthi, M. Shabnam Sulthan, and V. Vinitha. Study on the Effects of Polypropylene Fiber in Concrete Paver Blocks. International Journal of Construction Engineering and Planning, 3(2), (2017), 32-38.

[24] Muhammed, Rismy, and Deepthi Varkey. An experimental study on flyash based geopolymer pavement block with polypropylene fibre. International Journal of Innovative Science, Engineering & Technology, 3(8), (2016), 548 - 553.

[25] Sohaib, N., et al. Using Polypropylene Fibers in Concrete to achieve maximum strength. Proc. of the Eighth International Conference on Advances in Civil and Structural Engineering. (2018).

[26] Ngo, V.T., Khai Lam, T.Q., Dung Do, T.M., Nguyen, T.C. Nano concrete aggregation with steel fibers: A problem to enhance the tensile strength of concrete. E3S Web of Conferences, 135 03001, 2019. DOI: 10.1051/e3sconf/201913503001.

[27] Tran, H.Q., Khai Lam, T.Q., Do, T.M.D. Model of prefabricated concrete frame in the condition of southern Vietnam. E3S Web of Conferences, 135 03043, 2019. DOI: 10.1051/e3sconf/201913503043.

[28] Khai Lam, T.Q., Thi My, D.D., Ngo, V.T., Chuc Nguyen, T., Phuoc Huynh, T. Numerical simulation and experiment on steel fiber concrete beams. Journal Physics: Conference Series, 1425 012007, 2020. DOI: 10.1088/1742-6596/1425/1/012007.
[29] Ngo, V.T., Lam, T.Q.K., Do, T.M.D., Nguyen, T.C. Increased plasticity of nano concrete with steel fibers. Magazine of Civil Engineering, 93(1), 2020. Pp. 27–34. DOI: 10.18720/MCE.93.3

[30] Do, T.M.D., Lam, T.Q.K. Quality of Construction Works at the Design Phase. Lecture Notes in Civil Engineering, 70, 2020. Pp 15-24. DOI: 10.1007/978-3-030-42351-3_2

[31] Do, T.M.D., Nguyen, T.C., Lam, T.Q.K. Investigating the effectiveness of insulation for walls of buildings in Vietnamese climatic condition. IOP Conf. Series: Materials Science and Engineering, 869 032008, 2020. DOI: 10.1088/1757-899X/869/3/032008

[32] Ngo, V.T., Bui, T.T., Lam, T.Q.K., Nguyen, T.T.N., Nguyen, V.H. Experimental Evaluation of Nano Silica Effects to High Performance Concrete Strength in Early Age. IOP Conf. Series: Materials Science and Engineering, 869 032011, 2020. DOI: 10.1088/1757-899X/869/3/032011

[33] Do, T.M.D., Lam, T.Q.K., Ngo, V.T. Analysis of textile and steel fibers based reinforced concrete beam. IJMPERD, 10(3), 2020. Pp. 8033-8040. DOI: 10.24247/ijmperdjun2020763

[34] Ngo, V.T., Bui, T.T., Lam, T.Q.K., Do, T.M.D., Study the effects of nano-silica on crack toughness of high performance concrete base on double-K model. IJMPERD, 10(3), 2020. Pp. 8041-8050. DOI: 10.24247/ijmperdjun2020764

[35] Do, T.M.D., Lam, T.Q.K., Ngo, V.T., Nguyen, T.T.N. Analysis of high performance concrete with steel fiber reinforcement. IJMPERD, 10(3), 2020. Pp. 8139-8147. DOI: 10.24247/ijmperdjun2020772