Retraction

Retraction: Earthen blocks with Synthetic Fibres – A Review (IOP Conf. Ser.: Mater. Sci. Eng. 1145 012039)

Published 23 February 2022

This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

Retraction published: 23 February 2022
Earthen blocks with Synthetic Fibres – A Review

A Jesudass1, Gayathri2, K Harish3, S Sree Ram3 and S Mohammed Riyas3

1 Assistant Professor, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore 641008, Tamil Nadu, India.
2 Associate Professor, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore 641049, Tamil Nadu, India.
3 Student, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore 641008, Tamil Nadu, India.
jesudass@skcet.ac.in

Abstract. In recent times, sustainability in daily routine aspects is gaining momentum, which increases use of earthen material as a building material and it plays a vital role in the construction of any buildings, when it is enhanced with the fibres (PET, polythene, polypropylene etc.). This study presents the comprehensive review of earthen blocks reinforced with the synthetic fibres like (polypropylene, polyester, polyethylene, glass fibres, steel fibres, nylon fibres, polyvinyl alcohol) and discussed about the physical and mechanical properties of the earthen blocks reinforced with these fibres. The literature search was performed with the google scholar and web of science search engines. Polypropylene fibre, PET fibres, Polyethylene fibres have good strength when it is reinforced with earthen blocks. The soil and the fibres are stabilized with cement and chemicals respectively to make earthen blocks. The treatment of fibre before adding as a reinforcing agent and some tests are missing in many studies. Future studies can be conducted on the effect of fibre treatment and the performance of the synthetic fibre reinforced earthen block.

1. Introduction

Owing to the growing trends towards natural buildings, the application of earth-based construction materials has been greatly increased over many countries. Because earthen building is one of the modest and unspectacular forms of construction. It also provides good resistance towards seismic, high-strength, eco-friendly, energy-saving, and most importantly it provides sustainable development [1]. Large segment of people started to opt for traditional construction materials since it is locally available and it can improve the performance against water-induced durability issues and strength parameters [2]. This review study objective is to review state of art literature studies on various properties of earthen blocks in terms of physical, chemical and durability properties when fibres are added to it. Every method of mixing fibres into soil has its disadvantage of either being inefficient or uneconomical. Therefore, research is on for finding out a new method to reinforce fibres in order to increase strength parameters and to control the swelling property of clayey soil [3]. It is to be noted that soil with short fiber is performing good and is attracting interesting among geotechnical enthusiasts. It has been found that
studies on mechanical behaviour of soil with short fibers is comparatively low with that of other studies.[4-7]

The review presented here deals with the synthetic fibres used in earth construction materials. The fibres extruded from the one-use plastic water bottle was not found to be useful in enhancing the properties of soil. The masonry units with earthen blocks were always had a complaint of being low strength (both in compression and tension), brittle nature. By incorporating fibres into soil, it can drastically improve the resistance against non-elastic shrinkage, crack, impact and makes it more rigid [8]. When earthen blocks are reinforced with fibres, it is able to resist more loads by energy absorption, which makes them a viable product in earthquake prone regions [9]. By inclusion of fibres, the earthen blocks show better resistance against deformation. Natural polymer Alginate can be added as potential admixture where interparticle bonding is needed. It has been found that fibre reinforced earthen blocks has lesser water retention capacity than conventional alternatives. By using this chemical and synthetic fibres as a stabilizing and reinforcing agent it gives more than two times the strength of the normal stabilized block. To add strength to the theory, laboratory investigation results to complement about the potential usage of fibres in earthen materials which in turn can increase the resistance against plastic shrinkage, impact and increased toughness[10]. Studies indicate that significant improvement in post crack flexural behaviour when it is compared with blocks without reinforcement. Adding fibres improves the sorptivity behaviour as it improves the bond matrix. C.K. Subramania Prasad et.al. infers this observation when fibre content was limited. When kit fibre and bottle fibre are compared, later exhibited more sorptivity. [11-13] Sergio Neves Monteiro Declares that fibres should be even more concentrated to finish up a withstandable block.

2. Review methods

The review is done by analyzing the literature on earthen blocks reinforced with synthetic fibre which is taken from the google scholar search engine and web of science. Total of 50 literatures taken out of which 30 papers are relevant to earthen fibres with synthetic fibres and those papers are reviewed

This paper is segmented into three parts 1. Various available synthetic fibres and its properties, 2. Physical, Chemical and Durability properties of earthen block with fibres, 3. Review findings and conclusions.

3. Fibres - Characteristics

Fibres as it can be broadly categorized into man made and nature made. Synthetic fibres refer to fibres made on chemical synthesis whereas natural fibres refer to those produced by plants and animals. Adding onto this, many commercially available synthetic fibres possess user friendly functions such good elongation, resistance against water and deformation resistance. Synthetic fibres are cheaper and more durable than natural fibres.

The synthetic fibres discussed and reviewed here are Polypropylene, Polyester, Polyethylene, Glass, Nylon, Steel, Polyvinyl Alcohol. The main discussion is on the reaction of these synthetic fibres when reinforced with earthen materials which may vary on some values individually. The physical and mechanical properties of the fibres are given table 1 and 2 respectively.

3.1. Polypropylene (PP) Fibres

Polypropylene is a thermoplastic polymer It is produced by the chain growth reaction polymerization from the monomer polymer. Polypropylene Fibers when mixed with soil significantly increase the strength
parameters of soil and also to control the biodegradation in biological and chemical terms.[14]. Polypropylene is the second-most dominantly used (next topolyethylene). It is similar to polyethylene but it has more heat resistance than Polyethylene.

3.2. Polyester (PET) Fibres
Polyester is also one of the polymers and specifically it is ester in the main functional group. Commonly it is called as terephthalate. The wide application of the material is in textile industry. The fibers of the polyester are mostly spun together with fibers of natural originto make a cloth with mixed properties. Polyester when mixed with cotton can be really strong, exhibits good resistance to tear, wrinkle and shrinkage [15].

3.3. Polyethylene (PE) Fibres
Polyethylene or polythene is the most commonly used plastic in the current environment. It is a linear, man-made, addition, homo-polymer, primarily used for packaging from this fibre only plastic bottles, geomembrane,plastic bags and plastic films are manufactured. Identical polymers of ethylene make the polyethylene. Low density polyethylene is extracted at high pressure and high temperature, high density polyethylene is done with low temperature and low pressure. Polyethylene exhibiting thermoplastic behaviour, adding a percentage of it to soil can increase the fracture resistance of it. [16].

3.4. Glass Fibres
Numerous extremely fine fibres of glass bonds to form a glass fibres Glass wool, which is broadly marketed under the name Fiberglass which is frequently used as thermal building insulation. It is manufactured with the help of special bonding agents which traps air voids that ends up with low dense filled with air known as glass wool. Glass fibres when mixed with silty sandy soil improves the peak strength. [17].

3.5. Nylon Fibres
Nylon being a thermoplastic material, can be made into fibers, films by melting. It is result of number of repeated polymer links. Nylon was the first commercially successful synthetic thermoplastic polymer. Nylon when mixed with chemical additives can lead to lot of desired property improvements. Nylon fibers has wide commercial applications in fabrics and daily usable products. Its broad applications include flooring, reinforcement in rubber, in automobile components and in packaging industries.

3.6. Steel Fibres
Steel fibers used as an additive in concrete found to be beneficial in improving tensile strength of it. When reinforced in soil, it drastically improves the shearing strength of the soil. Its relative performance with other fibres is not much studied. [18].

3.7. Polyvinyl Alcohol Fibres
PVA (polyvinyl alcohol) Fibres are exceptionally high performing fibers when it is reinforced with concrete and mortar. Their quality to blend and creating molecular level bonding with mortar and concrete is significantly higher (upto 200 percent) than that of other fibres. When related with nylon and polyester PVA has lower shrinkage when heated [19-22]. Since it has higher resistance towards weathering and chemicals than PP fibres, it is mostly sought.
### Table 1. Physical Properties of fibres

| Fibres                        | Length (mm) | Diameter | Water Absorption | Thermal Insulation | Specific gravity | Reference |
|-------------------------------|-------------|----------|------------------|--------------------|------------------|-----------|
| Polypropylene (PP) fibres     | 6, 12, 18, 24, 35 and 50 | 0.30-0.35 | 0.03%            | 100-150×10⁻⁶       | 0.9              | [1]       |
| Polyester (PET) fibres        | 3, 6, 12, 20 and 64 | 101.5     | Low              | 80 x 10⁻⁶          | 0.96             | [4]       |
| Polyethylene (PET) fibres     | 12, 25 and 50 | 117       | Low              | 100 - 220 x 10⁻⁶  | 0.9              | [7]       |
| Glass fibres                  | 25          | 57        | -                | 100-150×10⁻⁶       | 2.2              | [3]       |
| Nylon fibres                  | 12, 10      | 110       | -                | 80 x 10⁻⁶          | 1.14             | [9]       |
| Steel fibres                  | -           | -         | -                | -                  | 1.20             | [13]      |
| Polyvinyl Alcohol Fibres      | 12          | 54        | -                | 100 - 220 x 10⁻⁶  | 1.27             | [11]      |

### Table 2. Mechanical Properties of fibres

| Fibres                        | Elastic Modulus | Tensile strength | Density      | References |
|-------------------------------|-----------------|------------------|--------------|------------|
| Polypropylene (PP) fibres     | up to 14.7 GPa  | 20 - 40 Mpa      | 0.855 g/cm³  | [1]        |
| Polyester (PET) fibres        | 10.6 GPa        | 10 - 123 Mpa     | 0.06 g/cm³   | [4]        |
| Polyethylene (PET) fibres     | 1.50 GPa        | 4.2 Gpa          | 0.88–0.96 g/cm³ | [7]     |
| Glass fibres                  | 72.4 GPa        | 200 Mpa          | 2.5 g/cm³    | [11]       |
| Nylon fibres                  | 2.7 GPa         | 82.7 Mpa         | 1.15 g/cm³   | [8]        |
Steel fibres
200 GPa
530 Mpa
8.05 g/cm3

Polyvinyl Alcohol Fibres
25 - 40 GPa
880 - 1600 MPa
1.3 g/cm3

4. Earthen Blocks - Manufacturing and Composition

4.1 Proportion and manufacturing

The basic composition of soil is gravel, sand, silt and clay depending on the particle size distribution. Soil generally exhibit low tensile strength and shearing strength properties, largely depends on the context and its formation characteristics [23]. Since it lacks in tensile and shear property, reinforcing certain materials with desirable properties can improve the soil in its strength parameters. The technique of adding fibers into soil to improve the engineering parameters (shear strength, compressibility, density ) of the soil is called as soil reinforcement [24]. Manufacturing process of the earthen blocks reinforced with synthetic fibres is varied with different methods and process according to the availability of resources, mostly the blocks are manufactured according to the test it has to be done, The nominal dimensions of blocks produced were 191 mm x 203 mm x121 mm and 229 mm x 203 mm x 121 mm, the weight of these blocks were found to be 9 and 11 kg respectively. For the first seven days, the blocks were cured with spraying of water and covered under plastic sheets. For the next 21 days, the blocks were kept under plastic sheets without curing. [25] and the length and proportion of the fibre reinforced are changed according to the fibres used mostly the fibre content lies between 0-5% and the fibres are added manually to get a homogeneous soil-fibre matrix and also the size and shape of the sample is depending upon the usage and test it has to be done for PET fibre 101.5mm diameter is taken and reinforced with soil and molded in cylindrical shape to obtain more strength in compressive strength test [26]

4.2 Compressing and Stabilization technique

Soil is compressed at high pressure to form blocks so only it is called as compressed earthen blocks or pressed earthen blocks.Compressing and stabilization is the most important process in the manufacturing of the reinforced earthen blocks, compression is mostly done using machinery and, in some cases, handmade hydraulic compressors are used to compress the earthen blocks. When soil (with calculated percentage of clay, silt, sand and gravel) is compressed with manual mechanical press, it refers to compressed earthen blocks. If the soil mix is stabilized with lime or Portland cement, it refers to stabilized and compressed earthen block. Pressure of around 21 Mpa is applied in compression to the soil mix to make the block and volume is reduced to 50 percent but in rammed earthen wall construction the whole soil-stabilizer-fibre are poured manually to the formwork and it is damped and compressed manually using rods and vibrators. Stabilization of soil refer to adding additives to enhance the strength and durability aspects of it to make it a good material for construction. Additives in the form of binders and fibres can be added to improve the properties of the soil. Stabilization can be achieved in many procedures, Mechanical, physical and chemical. Stabilization can be achieved in following methods, densification, reinforcement, cementation, linkage, imperviousness and waterproofing. Reinforcement refers to adding fibres and cementation refers to adding cement or lime. Cement stabilization is most important process to obtain immediate strength and 10 to 20 percentage of stabilizer is mostly added in all type of fibre reinforced earthen blocks to obtain high and immediate strength.
5. Features of Fibre Reinforced Earthen Block

5.1. Mechanical Properties

Earthen masonry is generally weak, brittle and poor at damage resilience but when it is reinforced with the synthetic fibres such as Polypropylene fibre at the length of 54mm and 27mm the mechanical properties of the earthen blocks are improved and especially compressive strength of the CSEB blocks are increased than the normal blocks and the proportion of adding fibres are varied according to the mechanical properties only and chitosan is also used as a reinforcing agent at 3% of adding it, it gives high mechanical strength properties. Recent studies have emphasized on enhancing the strength parameters of earthen materials with additives in soil mix. Two polymeric agents namely cationic amine and asphalt had very good performance when it is added in solution during mixing process, the compressive strength of earthen blocks increases by 80 percent moisture content has an important influence for the mechanical properties of the earthen materials the proportion of adding fibres also decide the mechanical properties and the range of adding fibres is 0 to 4 percent of its weight.

5.2. Physical Properties

The interfacial shear resistance of fiber/soil depends primarily on the rearrangement resistance of soil particles, effective interface contact area, fiber surface roughness and soil composition. When soil is reinforced with polypropylene, the unconfined compression strength was found to be increased, also shrinkage and swelling property of clay was found to be reduced. When Polyvinyl alcohol fibres was added, shrinkage due to heat was found to be lower when compared with nylon and polyester. PVA fibres exhibits good adhesive qualities to cement and possesses high alkaline characteristics. Due to these advantages PVA is highly sought material for reinforcements. With increase in fibre content, the resistance towards shrinkage, and conductivity of clay is increased. The shrinkage and swelling properties of clay when flyash and polypropylene fibres are mixed were also studied and reported. Results conclude that the mix of polypropylene and flyash affects the swelling and shrinkage characteristics of clay in a positive way. With increase in fibre, the water absorption was increased. These studies indicate, fibres creates interconnected channels that aids in improved water absorption.

5.3. Durability and Thermal Properties

Synthetic fibers are more durable than most natural fibers. Also, many synthetic fibers offer consumer-friendly functions such as stretching, waterproofing and stain resistance. Polyester is a most popular synthetic fibre because of its high durability. Thermal conductivity of synthetic fibre is far more than that of natural fibres.

6. Conclusion

The current study had done extensive review on usage of synthetic fibres in the earthen block. The fibres included were Polypropylene, Polyethylene, Polyethylene tetrathlate, nylon, Glass and steel. As a simple process, fibres, typically at a dosage rate of 0.2–4% by weight, are added and mixed with sand, silt, clay and stabilized with Portland cement or using chemicals on the basis of the model discussed in the review paper it clearly shows that the use of synthetic fibres as reinforcing agent in a perfect ratio increase the physical and mechanical properties of the earthen blocks in some cases the fibres are randomly distributed and the randomly fibre reinforced earthen blocks have peak shear strength and low post peak strength
although the fibre is reinforced to increase the strength of the blocks built with cohesive soils it also performed good at the other soils but its strength was peak at the cohesive soils in other cases researchers combined fibres with chemical binder such as polyvinyl alcohol and it also improves the stability of the soil and other case they decrease the ductile behavior of the soil. And the fibres helps to rectify the brittle behaviour of the earthen blocks. Locally available raw materials, less energy intensive manual pressing machines, ease to work with, its flexibility to be used in all climates are its much-acclaimed advantages of fibre reinforced earthen blocks.

Reference

[1] Peter Donkor, Esther Obonyo, Fabio Matta, 2014, Ece Erdogmus Effect of Polypropylene Fiber Length on the Flexural and Compressive Strength of Compressed Stabilized Earth Blocks, Construction Research Congress, ASCE 1661-669
[2] Lynnette, 2017, Widder Earth eco-building: textile-reinforced earth block construction, Energy Procedia 122, 757-762
[3] Galán-Marín C. Rivera-Gómez C. and Bradley E., 2013, Ultrasonic Molecular and Mechanical Testing Diagnostics in Natural Fibre Reinforced, Polymer-Stabilized Earth Blocks, International Journal of Polymer science, 2013
[4] Peter Donkor, Esther Obonyo, 2015, Earthen construction materials: Assessing the feasibility of improving strength and deformability of compressed earth blocks using polypropylene fibres, Materials & Design 83, 813–819.
[5] Subramani Prasad C K, Benny Mathews Abraham, Kunhanandan Nambiar E K, 2014, Sorption characteristics of stabilized soil blocks embedded with waste plastic fibres, Construction and Building Materials 63, 25–32
[6] Subramani Prasad C K, Benny Mathews Abraham, Kunhanandan Nambiar E K, 2014, Water absorptivity of stabilized soil blocks reinforced with waste plastic fibres, Construction and Building Materials 63, 25–32
[7] Cassandra A Dove, Fiona F. Bradley, Siddharth V. Patwardhan, Seaweed biopolymers as additives for unfired clay bricks, Materials and structures 49, 4463-81
[8] Sayyed Mahdi Hejazi, Mohammad Sheikhhaadeh, Sayyed Mahdi Abtahi, Ali Zadhoush, 2012, A simple review of soil reinforcement by using natural and synthetic fibers Construction and Building Materials 30, 100–116
[9] Subramani Prasad C K, Benny Mathews Abraham, Kunhanandan Nambiar E K, Plastic Fibre Reinforced Soil Blocks as a Sustainable Building Material. International Journal of Advancements in Research & Technology, 1
[10] Sergio Neves Monteiro, Foluke Salgado de Assis, Carlos Luiz Ferreira, NoanToniniSimonassi, Ricardo Pondé Weber, Michelle Souza Oliveira Henry A. Colorado and Artur Camposo Pereira, 2018, Pique Fabric: A Promising Reinforcement for Polymer Composites, Polymers, 10, 246
[11] Movcenuddin A. Sawpan, Kim L. Pickering, Alan Ferny Hough, 2011, Effect of fibre treatments on interfacial shear strength of hemp fibre reinforcedpolyolactide and unsaturated polyester composites Composites: Part A: Applied science and manufacturing 42, 1189–1196
[12] Ernest Benat-Maso, Lluis Gil, Christian Escrig, 2016, Textile-reinforced rammed earth: Experimental characterization of flexural strength and toughness. Construction and Building Materials 106, 470–479.
[13] C. K. Subramania Prasad; Benny Mathews Abraham; and E. K. Kunhanandan Nambiar , 2015, Influence of Embedded Waste-Plastic Fibers on the Improvement of the Tensile Strengthof Stabilized Mud Masonry Blocks, Journals of Materials in Civil Engineering 27
[14] Rafael Aguilar, Javier Nakamatsu, Eduardo Ramírez, Mariela Allergen, Jorge Ayarza, Suyeon Kim c, Miguel A. Pando d, Luis Ortega-San-Martin, 2016, The potential use of chitosan as a biopolymer additive for enhanced mechanical properties and water resistance of earthen construction. *Construction and Building Materials* **114**, 625–637.

[15] Prakash Duraisamy, Xiaohui Yuan, ElSaba, A. and Sumithra Palanisamy, Contrast enhancement and assessment of OCT images, Proceedings of International Conference on Informatics, Electronics & Vision (ICIEV), 2012 Date: 18-19 May 2012 pp.91-95(Location :Dhaka, Print ISBN: 978-1-4673-1153-3,INSPEC Accession Number: 13058449, Digital Object Identifier:10.1109/ICIEV.2012.6317381)

[16] Sumithra M. G., Thanushkodi, K. and Helan Jennifer Archana , A. A New Speaker Recognition System with Combined Feature Extraction Techniques, *Journal of Computer Science*, Vol. **7**, Issue 4, pp.459-465, 2011. (With impact factor SNIP of 0.162 and SJR 0.034).

[17] Bueno S. The mechanical response of reinforced soils using short randomly distributed plastic strips. 1998, *Recent developments in soil and pavement mechanics* 401-408

[18] Masumi E, Abtahi M, Sadeghi M, Hejazi M, Compressive behavior of composite soils reinforced with polypropylene fiber and polyvinyl alcohol, 5thSASTech, 2011

[19] Kumar S, Tabor E,.2003 Strength characteristics of silty clay reinforced with randomly oriented nylon fibers. The *Electronic Journal of Geotechnical Engineering*, **127**, 774–82.

[20] Rowell M, Han S, Rowell S. Characterization and factors affecting fiber properties. *NaturalPolymers Agro Composites*, 2000115–34.

[21] Kaniraj R, Gayathri V. Geotechnical behavior of fly ash mixed with randomly oriented fiber inclusions. *GeotextileGeomembrane* 2003**21**, 23–49.

[22] Abtahi M, Sheikhzadeh M, Hejazi M, Hassani Y. Compressive behavior of composite soils reinforced with recycled waste tire cords and polypropylene fibers. In: *1st Int and 7th national conference of textile engineering*, Rasht, Iran; 2009.

[23] Ling I, Leshchinsky D, Tatsuoka F. Reinforced soil engineering: advances in research and practice. Marcel Dekker Inc.; 2003.

[24] Humphrey Danso, D. Brett Martinson, Muhammad Ali, John Williams, 2014, Effect of fibre aspect ratio on mechanical properties of soil building blocks, *Construction and Building materials* **83**, 314-319.

[25] Mahgoub M. Salih, Adefaja I. Osifere, Mohammed S. Imbabi, 2020, Constitutive models for fibre reinforced soil bricks, *Construction and Building Materials* **240**, 117806.

[26] Sawicki A. Plastic limit behavior of reinforced earth. Journal of Geotechnical Engineering 1983, 109