Examining the Efficiency and Effectiveness of Alternative Material for the Interlocking Prefabricated Sandwich Panel

Roman Man Shrestha*, Ajay Khadka**

**Asian Institute of Technology, Bangkok, Thailand*

***Nepal Engineering College, Changunarayan, Bhaktapur, Nepal*

***ajayk@nec.edu.np*

Roman Man Shrestha *is studying master degree at Asian Institute of Technology, Bangkok, Thailand.*

Ajay Khadka *has received his Master degree in Construction Management from Pokhara University.He has been involved in teaching profession for last 11 years and is currently working as an Assistant Professor and Head of Civil Engineering Department at Nepal Engineering College. His research interest is in earthquake safety constructions.*

ABSTRACT

The paper shows the effective utilization of non-degradable waste material like the hair of humans, Expanded Polystyrene Spheres (EPS), and rice husk fly ash to a final product Fiber-reinforced concrete panel. Concrete fracture, catastrophic failure, spalling of concrete and non-quake resistance, with the application of a load are major problems of the current scenario in the concrete world (Mindess, 2009). This paper tries to solve this type of problem by using the natural fibers and some additives which are under patient right. The researcher of this paper has developed a prefab panel which may be the substitute product of brick, ACC block, interlocking block, EPS panel, and local prefab panel. The utilization of industrial waste to usable products for construction is a major challenge that the researcher has taken. The paper shows that product can be made economical and able to reduce environmental challenges. Ingredients like human hair, EPS, chemical agent, cement, fly ash, water, and fiberboard are utilized in a certain time and fixed condition to complete the formation of the Fiber-reinforced concrete panel. The panel was found to have multi-function like a light in weight, fireproof, and flexibility which was its main USP (Unique Selling Point). The researcher thinks this product might change the perception of Nepalese customer, who thinks prefab as a costly and less strength product. Nepal political instability and dependent culture on foreign country shows an impossible possibility to use an artificial fiber and imported fly ash (ITC, 2017). This paper also presents the Nepalese market perception through the business model canvas, a business strategy that can be taken, hindrance, and the possibility to use human hair fiber, fly ash and recycled EPS to complete finished goods.

Keywords: *Fiber-reinforced concrete, compressive and flexural strength, prefab panel, sustainable environment*

1. INTRODUCTION

Increasing service loads, extreme loading events, and constant exposure to an ever-changing ambient environment are just a few reasons why civil structures, over extended service periods, degrade and ultimately become structural deficient (Ellingwood, 2005). The 1980s saw the advent of more cost-effective means to manufacture advanced fiber-reinforced polymer (FRP) composite materials; making the use of such materials more suitable for construction purposes. By the late 1980s, numerous researchers began investigating the possibilities of using FRPs to strengthen reinforced concrete structures. With excellent corrosion resistance, high strength-to-weight ratio, and stiffness-to-weight ratio, externally bonded FRP composites provided time and strength efficient means to strengthen reinforced concrete (RC) structures which latterly synonym into Fiber-reinforced concrete (Haber, 2007); (Bakis et al., 2002). Fiber-reinforced Concrete (FRC) was patented and developed by French gardener Joseph Monier. The concept of using fibers as reinforcement is not new, but in our country Nepal, this concept is new and no any research work has been done in this field. According to Gupta & Sharma (2018), fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. Typically this type of mechanism can be seen in Bardia and Kailali of Nepal, where people are using hair, straw, and husk for making their home. In the 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into but due to health risk asbestos was discouraged. New materials like steel, glass and synthetic fibers replaced asbestos for reinforcement. FRC consists of composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers. Fibers include steel fibers, glass fibers, synthetic fibers, and natural fibers. Recently, organic and synthetic fibers such as acrylic, aramid, carbon, nylon, polyester, polyethylene, and polypropylene have also been used (McIntyre, 2004).

Concrete is weak in tension; to overcome this deficiency, human hair can be the best option to increase the strength of concrete. Ganiron (2014) presented the effects of human hair additives in compressive strength of asphalt cement mixture as a potential binder in road pavement. It stated that the elastic property of the hair fiber-reinforcement in an asphalt pavement may produce better stand on traffic loading i.e., increases the strength by the same fundamental mechanism of transferring the high-intensity forces imparted at the surface by the wheel loads to lower levels than the subgrade can accommodate without deforming. According to Batebi et al., (2013) the main element of hair composition is keratin which are proteins with long chains of amino acids that form the cytoskeleton of all cells of the outer shell. Several investigations stated that sulphur is the main reason for strength hair cords in front of disintegration in the face of environmental stress and these Sulphur compounds are linked with amino acids. Sulphur in amino acid molecules is adjacent to keratin protein so it forms a di-sulfide chemical chain (chains are very strong and resistant to breakage). These chains are very resistance to acids di-sulfide performance, but in alkaline solutions, they can be decomposed (Brosnan, 2014). As the alkaline environment loses the hair cords, we must be aware not to take hair cords in alkaline solutions. The outer layer of hair is called "Cuticle" which is much like tree trunks and bumps (Moll & Langbein, 2008). Hair diameter is 50 to 100 micrometers. In this study, hairs of 80 micrometers were used and bumps on hairs were of nano size. These bumps help to lock cement mortar.

2. OBJECTIVE OF THE STUDY

2.1 Main objective

The main objective of this paper was to see the feasibility of light weight ductile concrete panel by using a natural fiber like human hair, fly ash, EPS, cement and chemical additives with certain time of addition and required quantity.

2.2 Specific objectives

1) To investigate the human hair generation from Madhyapur Thimi Municipality and check the demand and supply.
2) To examine the compressive strength, flexural strength, sound test and fire test of prefabricated sandwich panel.
3) To analysis the business viability of prefab panel in Nepalese market.
4) To compare the prefabricated sandwich panel with other substitute construction material.

3. METHODOLOGY

Two research methods were focused for successful completion of this project. They were:

- Survey Method
- Experimental Method

3.1 Survey Method

The research was done to find out the total amount of hair collection from Ward No 3, 4, 5 and 6 in Madhyapur Thimi Municipality. Around 6,771 males and 6,376 females with 2,968 households are living over there (CBS, 2011). The survey was carried out in two categories, one in beauty parlor and one in the male saloon. Moreover, a questionnaire survey was carried out with the owner of those parlors and saloons. From that survey, 10 male saloons and 7 beauty parlors are taken down. After the evaluation of waste human hair in the saloon, it was observed that the hair sample was too dusty and needed more treatment than that of beauty parlors. Mixing of beards and hairs increases the complexity of processing of the hairs. The average amount of hair collection was calculated as:

Average Amount of Hair obtained =

$$\frac{\text{Total Weight of Hair Obtained from Parlor}}{\text{No of parlor}}$$

= 3.475kg

Average Amount of Hair obtained =

$$\frac{\text{Total Weight of Hair Obtained from Saloon}}{\text{No of saloon}}$$

= 10.799kg

A total of 3.475kg from one beauty parlor with 15% wastage and 10.799kg from one saloon with 35% wastage were found. Waste like beard and some unfluctuating disperse hair comes from saloon so we have taken maximum wastes percentage than that of beauty parlor obtained from 4 wards of Madhyapur Thimi Municipality. The researcher of this paper found 1,091kg of hair from the survey done on Aug 4, 2017, whereby calculation, it is enough to develop 2,100 numbers of prefab board. If (7'*2') panel of NRs 4,172 is taken then it could generate a rough number of NRs. 8,761,200. This survey shows there will be enough material and it is feasible to implement the project.

3.1 Experimental Method

3.2.1 Material Used

Portland cement with 43 grade and specific gravity of 3.15 was used. The sand used for the experiment was locally procured and sieved through 4.75mm sieve to remove any particles greater than 4.75mm and was then washed to remove dust. As for the testing for the flexural test, sand was sieved from 1.7mm sieve. The coarse aggregate used in this experiment was 25mm sieve and was crushed in angular shape. The aggregates are made free from dust before being used in the concrete. Hair of diameter 80~120 µm with a length of ongoing patented length was also used.

Table1: Hair specifications (Moll & Langbein, 2008)

Property	Value
Hair diameter	80 to 120 µm
Hair length	60mm** used for experiment
Aspect ratio	500 – 600

Water used in the experiment was clean and safe for mixing as well as the curing of concrete specimens. Rice husk used was an agro-industrial by-product with high silica content. With proper incineration and controlled burning, this husk becomes a pozzolanic material that can be used for replacement of cement at various percentages of dosage (Alireza et al., 2017). It was oven-dried and sieve in 0.075mm sieve for making the product. Expanded polystyrene is a polymer resin obtained by heating and curing the polystyrene resin to generate foams. Expanded polystyrene is white, light in weight, and has superior water resistance, thermal insulation, sound absorption and buffering properties. Its cells are not interconnected, so heat cannot pass through it easily, making it a great insulator. The mix design process was done which is a process of selecting suitable ingredients of concrete and determining their relative amounts needed to produce concrete of the required, strength, durability, and workability as economically as possible. In this study, variation of mixing has been done to achieve the strength.

3.2.2 Compressive strength test (on cubes):

The compressive strength of concrete is its ability to resist a crushing force. It is the ratio of load at the failure to the surface area of concrete specimen. The compressive strength test is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test must be carried out on specimens cubical in shape of the size 150 × 150 ×150 mm (Jiang et al., 2017). The results from the compression test are obtained from the destructive test and non-destructive test (Schmidt Hammer).

Cube compressive strength (f_{ck}) in MPa, $\sigma = \frac{P}{A}$

Where,

P= Cube compression load in Newton (N)

A= Area of the face of cube on which load is applied (i.e., 150*150=22500 mm^2)

3.2.3 Flexural strength test

A flexural test is the most common procedure used to measure the tensile strength of concrete. Although concrete is not designed to resist direct tension, the knowledge of tensile strength is of importance in estimating the load under which cracking develops. The test is very useful especially in relation to the design of road slabs and runways because the flexure tension is a critical factor in these cases. The system of loading used in finding out the flexural tension is Third-point Loading Method (Mallick et al., 2014).

The modulus of rupture is calculated using the formula

$$\sigma_b = \frac{PL}{bd^2}$$

Where,

P= Breaking load in N at which specimen fails

L= Length in mm of the span on which the specimen is supported (600)

B= measured width in mm of the specimen (150)

d= measured depth in mm of the specimen at point of failure (150)

3.2.4 Sound Test

The researcher of this paper made a homemade incubator, which was enclosed by close clear glass. A clear glass of size (15”*6”*6”) was made by enclosing with hot glue and silica with 100W hot melt glue gun was used to make air gap box. The 6”*6”*4” specimen was placed into the glass box. The intensity of sound was measured by decibel (dB). Sound Meter Apps was used to note down the maximum and minimum decibel (dB) and a stopwatch was used with 2:20sec targeted time for both of specimen.

3.2.5 Fire Test

Fire test was done to check the resistance to fire. As recommended procedure done by Lukaszewska et al. (2010), surface test was done where researcher of this paper compared with local prefab panel. The main doubt was whether the hair and EPS will burn in fire or it will capture the fire but the result was positive where the material bounded by the cementations material and it is impossible to catch fire. Three tests were done to check the prefab board. 4 hours continuous fire was given in specimen so that comparison between local prefab and our panel can be made. After the evaluation, we have found that the local panel was separated from internal EPS bonding but in case of our panel, the result was completely different. We found that the surface of prefab panel has little crack. Surface spread of flame test was also done by using the petroleum product but in this test, no change was found in both prefab panels.

4. RESULTS

4.1 Compressive strength test

A test was done in RCC lab of Pokhara Engineering College (PEC), Phirke, Pokhara on 2073/12/15 (28 March, 2017) with an experiment ratio of 1:1:2 with sample name R1, R2, and R3. The study was done to know whether the addition of human hair will improve the strength of concrete. The study found that the addition of human hair can improve an average of 5% of strength than normal concrete.

Fig1: Hair sample test with addition of hair in concrete on 2073/12/15

4.2 Flexural Strength Test

A test was done in RCC lab of Nepal Engineering College *(nec)*, on 2074/4/14 (8 August, 2017), with experiment ratio of 1:2:4 with sample name (sample 1, sample 2, and sample 3) with water-cement ratio of 0.6, 0.8 in normal plain cement concrete, and 0.8 additive hair concrete. The study was done to know whether the addition of hair might increase flexural strength or not. The modulus of elasticity of hair added concrete was found to be 3.048 N/mm2 which shows there is increase of 17% strength than that of normal concrete with w/c ratio of 0.6 and 13% than that of normal concrete with w/c ratio of 0.8.

Table 2: Result for Flexural strength test in addition of hair

Specification	Date of testing	bd^2	Breaking Load (P)	Modulus of Rupture, $\sigma_b = \frac{PL}{bd^2}$
Sample 1	2074/4/22	3375000	1498.98 kg	2.61 N/mm²
Sample 2	2074/4/22	3375000	1548.95 kg	2.70 N/mm²
Sample 3	2074/4/22	3375000	1748.81 kg	3.048 N/mm²

Fig 2: Flexural strength test of three point loading method

4.3 Schmidt Hammer test or rebound Hammer test

This test was done in RCC lab of Nepal Engineering College (nec), on 2074/4/14 (29 July, 2017), with different sample size as sample 1 (10”*10”*4”), sample 2 (10”*10”*2”), and sample 3 (10”*10”*2” inside pipe hollow). The rebound hammer test is a non-destructive test from where the researcher of this paper expects to get the required compressive and flexural strength of the sample without deformation of the material. In sample 1, the rebound number was found 21.22 which is less than 16% of that of sample 2 and from calculation of using graph we get 60% compressive strength of 8.4 N/mm2 which was 17% less compressive strength that of sample 2 and flexural strength of 2.02 N/mm2 which was 15.34% less than that of sample 2. The compressive strength of pipe hollow prefab panel (sample 3) was 11.4 N/mm2 and compressive strength of 2.36 N/mm2 with a rebound number of 20.11. This study shows that the pipe hollow prefab panel is stronger and efficient than that of normal prefab panel.

Table 3: Result of Schmidt hammer test

Specimen	Rebound Number	Weight	60% compressive strength	Flexural strength $(0.7\sqrt{fck})$
Sample 1	21.22	4.348	8.4 N/mm²	2.02 N/mm²
Sample 2	24.778	2.420	11.1 N/mm²	2.33 N/mm²
Sample 3	20.11	3.044	11.4 N/mm²	2.36 N/mm²

Fig 3 : Rebound hammer and Flexural test sample

4.4 Sound Testing

Sound testing was done by comparing the sound measurement between local prefab panel and our prefabricated prefab panel in-terms of decibel (dB). The time duration to check was 2.20sec with the utilization of sound meter app in a closed glass box. The mean dB of our prefab panel was 50 dB which was 4% more sound resistance than that of locally available prefab panel.

Table 4: Result of sound test

Panel	Time	Lowest dB	Highest dB	Mean dB
Local Prefab panel	02:20sec	17dB	83dB	52dB
Our Prefab Panel	02:20sec	17dB	84dB	50dB

Fig 4: Fire and sound test

5. BUSINESS STRATEGY

There must be feasibility and viability of any project before taking it to the field. Business strategy is also one of the measurements which will show the risk factor of the project and future market perception of the customer. To see the real picture of the project through a business plan, this paper evaluates some business strategy terms. The analysis will help to find out the strategies, analytical and decision-support tools that can create value for the customers. The analysis focuses on documentation plan on how a project is setting out to achieve their goals. A business strategy contains a number of key principles that outlines how a project will go about attaining these goals. For example, it will explain how to deal with your competitors, look at the needs and expectations of customers, and will examine the long term growth and sustainability of the project. Business strategy tries to remedy the weaknesses so that the project doesn't trip up and suffer their impact too greatly. Strategies look at these future risks and help develop ways in which they can overcome these obstacles. A well-defined business strategy will offer a guide on how a project is performing internally. It will also guide on how the project is performing against competition and what are needed to stay relevant in the future. Basically this paper also addresses the issues such as, customer retention, resources and project expansion in the near future of prefab panel.

5.1 Business Model Canvas

The nine factors were used to measure the business model canvas as mentioned by Michal Porter. The business model canvas shows a clear picture of the business after the production of material and what the researcher will try to do in the future to meet the project objective. The first factor is the customer segment which means who will be the customer after the production of the prefab panel. The customer will be an executive member of the company, experienced engineers and high class of contractors. The owners are less informed than that of consultant and contractor so we haven't focused on them. Second, value proposition which means what value we are trying to give them to attach them with us. We are delivering a high strength concrete lightweight prefab panel and solving the quality-related problems of customer. The main thing is satisfying their needs, fast installation, risk reduction and cost reduction of a product. Customer relationships have a key role in business. We are focusing on long term relationships with maintenance-free service for our customers where we focus on three V's (valued customer, value proposition and value network). The customer segment will be the people working in the construction line, majorly focusing on consultant and experienced contractors. For key activities to get the desired material, we need to focus on the design, manufacturing, delivery and quality control section. The channels, we are using will be both physical and virtual channels like newspapers, TV and YouTube advertisements. The key resources needed for us will be the specialized machines and equipment to provide effective and efficient work value to customers. Equipment like air dry segregator, 50 kg kneaded machine and some advance oven dryer will be needed. To support our business there will be a need for key partners or stakeholders. There will be a need for strategic alliances with NEA, FCAN, and the owner of crusher factories. The cost structure for the project is majorly investment on assets at first stage and production cost at the second stage. The revenue streams of the project are from the selling of the finished product implementing a manufacturing model by providing a product containing a value with lightweight, flexible and high-quality products.

5.2 PESTLE Analysis

PESTLE Analysis is a framework for assessing the key features of the external environment facing a project. The purpose of a PESTLE analysis is to identify all of the various external political, economic, social, technological, legal and environmental factors that might affect a project. For instance, a new prefab panel factory might create a problem like chemical issue in river breaking local bylaws which can be found from a PESTLE analysis. This might prompt the factory to institute a policy on environmental rules and regulation. Political factors will be fluctuation in laws, rules, and change in bylaws with the policy in 7 provinces. Economy factors can cause by labor and energy costs. The fluctuation in the price of plants, equipment and construction goods will also be a major economic factor for our project. The social factor may cause in the future may be continuous holiday by provincial rules and local strikes. The technological factor will be emerging technologies that may be competitive with our projects like new technology like interlocking brick and polystyrene sandwich panel. The legal factor that may cause difficulty in implementation will be trade union culture and 8-hour schedule work which will be a major factor to control human skills. The environmental factor may be challenging to control carbon emission and regulate the CO_2 emission of our panel between 90gm.

5.3 SWOT Analysis

SWOT analysis is a strategic analytical and decision-support tool that highlights the bases where businesses can create value for their customers. SWOT-analysis helps a project to find out the competitive strength and the nature of its external and internal environment. SWOT means strength, weakness, opportunities, and threats of the project. Strengths and weaknesses are related to the internal issue of the project and opportunities and threats are related to the external issue of the project. The strength of the project is requirement of less amount of skilled manpower. The product has more strength and less cost than that of the local prefab panel. It also has more quality and finishing than that of local prefab panel. A major strength is that all raw material needed to build a prefab panel are available in-country and flexibility of the product, so can be used for several times. The weakness of the product is that it is costly than that of normal brick and need of well-equipped factory and the major thing is necessity to change the perception of Nepalese people about the prefab panel. The opportunities for the project are rising market in Nepal and slightly changing consumer preference and government preference for the industry. Every business has a threat and the main threat of the project is the emergence of new competitors, idea circulation in negative form and migration of skilled manpower.

6. ANALAYSIS AND DISCUSSION

Fig 5: Sketch up design of Our Panel required for 1369 sq.ft

The researcher of this paper has compared the normal brick and locally available prefab panel. A calculation has been done to make a clear vision and measured it through various factors. Here in this paper, researcher has focus on product but not in structure of development. We assumed the size of area land as 1369 sq. ft. which equals to 4 anna. The number of normal prefab panels of size (7'*2.5') will be 76 no's but our panel of size (7'*2') will be of 82 no's. The requirement of brick for this project will be 9815 no's. The cost of the local prefab with 90mm breadth at the rate of NRs 450 per sq ft will be NRs 513000 which is 42% higher than that of brickwork for the project and 31% higher than that of our panel (4' breadth with the rate of NRs 298 per sq ft). It suggests that our panel will be 9% expensive than that of brickwork.

6.1 Comparison with substitute product

The comparison shows the main difference in terms of technical view. The researcher has chosen five different substitute materials to know the different qualities and strengths of the product. All result was found by an experiment done in the different lab of Nepal Engineering College *(nec)*.

6.1.1 Minimum compressive strength

The five different samples were tested in the Nepal Engineering College *(nec)* RCC lab. The result for minimum compressive strength of our panel of sample size(6"*6"*4") was found 10 N/mm2 which is 45% more than interlocking hollow brick of sample size (7"*6"*4"), 53% more than local prefab panel of sample size of (6"*6"*4"), 70% more than that of AAC block of sample size (26"*8"*8") and 4% more than that of normal brick of sample size (9"*4"*2").

6.1.2 Fire resistance

The sample was tested in 2 different places. The fire resistance of our panel of sample size (6"*6"*4") was found in category of class A and resists heat up to 4 hours where no changes were seen. The local prefab panel of sample size (6"*6"*4") was found some deformation in the sample after 4 hours.

6.1.3 Dry density

The five different samples were tested in the Nepal Engineering College Hydrology lab. The result for the minimum compressive strength of our panel of sample size (6"*6"*4") was found 721kg/m3 which was able to float on water. The dry density for interlocking was found to be 1600 kg/m3 and AAC block of sample size (7"*6"*4") was found to be 650 kg/m3, local prefab panel of sample size of (6"*6"*4") had 750 kg/m3 and normal brick of sample size (9"*4"*2") had 1800 kg/m3.

7. CONCLUSION

From this research, survey and experimental work, we have concluded that addition of human hair fibers makes concrete more homogeneous and isotropic and it will transform from brittle to more ductile material. The researcher of this paper concluded that by the collection of human hair from a certain local area, the actual requirement can be fulfilled. Researchers concluded that by the addition of human hair, there is an increase of 12.88% flexural strength than that of normal concrete. In the case of prefab panel, compared with our panel, it is found to have double compressive strength than that of existing prefab panel.. In-case of sound and fire test, our panel was more resistant than that of normal available prefab Panel. In-case of cost comparison, our prefab panel is 31% cheap than that of other prefab panel and 9% costly than that of brickwork. Our prefab panel is energy-saving, flexible, lightweight, well finished and environmental friendly. It can be used in various building additions or renovations for interior wall, exterior wall, roof and floor on steel or in the concrete structure. As a number of the experiment was done in various sizes, we can provide several sizes of the panel as per future customer requirements. We have found that microcracks form in concrete was arrested by the fibers. Thus improved strength and ductility, and under loading, reinforced fibers will stretch more than concrete. The research concluded that there will be a remarkable increment in properties of concrete such as compressive strength, modulus of elasticity, flexural strength and impact resistance, according to the exact ratio addition of rice husk ash, human hair, EPS, cement, and chemical additive.

Note: Our research based on panel size as available in market so we used random sizes for test in lab. We did not use concrete test as per standard cube size. Again our unit is based on regular using unit in practice of construction field in Nepal.

REFERENCE

[1] Ahmed, M., Mallick, J., & Hasan, M. A. (2016). A study of factors affecting the flexural tensile strength of concrete. *Journal of King Saud University-Engineering Sciences*, *28*(2), 147-156.

[2] Brosnan, J. T., & Brosnan, M. E. (2006). The sulfur-containing amino acids: an overview*: The Journal of nutrition*, *136*(6), 1636S-1640S.

[3] Batebi, Y., Mirzagoltabar, A., Shabanian, S. M., & Fateri, S. (2013). Experimental investigation of shrinkage of nano hair reinforced concrete. *Iranica Journal of Energy & Environment, Special Issue on Nanotechnology*, *4*, 68-72.

[4] CBS. (2019). Retrieved from https://unstats.un.org/unsd/demographic-social/census/documents/Nepal/Nepal-Census-2011-Vol1.pdf. Accessed on (April 16, 2019)

[5] C. E. Bakis, L. C. (2002). *Fiber-Reinforced Polymer Composites.* ASCE.

[6] Ellingwood, B. (2005). *Risk-informed condition assessment of civil infrastructure: State of practice and research issues.*

[7] Ganiron, T. U. (2014). Effects of Human Hair Additives in Compressive Strength of Asphalt Cement Mixture. *ASCE*.

[8] Gyawali, T. R., Maeda, M. K., Yamada, K., & Uchida, A. (1996). An investigation on properties of EPS concrete mixed using new-type mixer. *Maeda Research Institute Technical Report, Maeda Corporation, Japan*, 9-16.

[9] Gupta, S., & Sharma. (2018) *A human hair as fiber material in reinforced concrete*. Graphic Era University

[10] Haber, Z. (2010). *On the Use of Polyurethane Matrix Carbon Fiber Composites for Strengthening Concrete Structures*. *University of Central Florida*

[11] ITC. (2017). *Nepal: Company Perspectives. An ITC Series on Non-Tariff Measures.* Geneva: International Trade Centre.

[12] Jiang, D., Xiao, C., Chen, T., & Zhang, Y. (2019). Experimental Study of *Tariff* High-Strength Concrete-Steel Plate Composite Shear Walls. *Applied Sciences*, *9*(14), 2820.

[13] Lukaszewska, E., Fragiacomo, M., & Johnsson, H. (2009). Laboratory tests and numerical analyses of prefabricated timber-concrete composite floors. *Journal of structural engineering*, *136*(1), 46-55

[14] Matin, H. H. A. (2018). Biogas Production from Rice Husk Waste by using Solid State Anaerobic Digestion (SSAD) Method. In *E3S Web of Conferences* (Vol. 31, p. 02007). EDP Sciences.

[15] McIntyre, J. E. (Ed.). (2005). *Synthetic fibres: nylon, polyester, acrylic, polyolefin*. Taylor & Francis US.

[16] Mindess, S. (Ed.). (2019). *Developments in the Formulation and Reinforcement of Concrete*. Woodhead Publishing.

[17] MoF (2019). Retrieved from https://www.mof.gov.np/en/archive-documents/budget-speech-17.html. Accessed on (April 15, 2019)

[18] Moll, R., Divo, M., & Langbein, L. (2008). The human keratins: biology and pathology. *Histochemistry and cell biology*, *129*(6), 705.

[19] NMCflyash (2019). Retrieved from https://www.nmcflyash.com/pozzolan/. Accessed on (April 6, 2019)

[20] Zareei, S. A., Ameri, F., Dorostkar, F., & Ahmadi, M. (2017). Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties. *Case studies in construction materials*, *7*, 73-81.

***