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Patent Analysis on Fiber Reinforced Material for Green Building

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ABSTRACT

Steel production releases high carbon dioxide emissions, whereas natural fibers are renewable and biodegradable. Glass fiber is lightweight but vulnerable to alkali attack and brittle whereas synthetic fibers are good for crack resistance but limited structural strength. Natural fibre can be used reinforced materials in building construction. In this study, the use of natural fiber materials as sustainable and eco-friendly alternatives for green building applications has been studied through patenting trends. Natural fiber reinforcing materials are cheaper, ecofriendly, lightweight, and provide good crack resistance. Non-wood-based natural fiber like straw, jute, coir, bamboo, sisal can be used to reinforce cement, concrete, and other building materials. Patenting trends with country wise priority application indicate that China, Germany, U.S, Korea, France are the most patent filing country on that subject area. However, the patenting trends on natural fiber reinforced concrete in India has not reached to a significant mark. The same may be due non establishment of domestic market on those materials in India.

Keywords: *Natural Fiber Reinforced Composite, building construction, green building, Fiber reinforced concrete, non -wood based natural fiber.*

1. INTRODUCTION

The notion of green building falls within the context towards going green program. Green buildings may promote sustainable development. At present, there is a Global trend to use green energy efficient and sustainable materials in building construction. This trend requires a

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shift from dependence on traditional building materials such as aluminum and steel to more affordable and more sustainable alternatives like natural fiber and or bio-composite. Natural Fiber reinforced composites are gaining significant application in the building construction. Researcher have been increasingly using natural fiber as substitute for steel or man-made fibers to be used in composite building material.

The research focus on green building construction material has increased expeditiously after 2000. Although several technical, economic, and regulatory challenges remain, green construction materials have emerged as a key driver of sustainable development in the construction industry.[3]Although, the application of natural fiber as structural and constructional element is not new. However, there is no systematic approach to study the fundamental mechanism and its interpretation on strengthening of structures and performance. Hence, the interest in natural fiber-reinforced polymer composite materials has been growing rapidly both in terms of their industrial applications and fundamental research[4].

In fiber reinforcement, fiber generally is used as reinforcement within matrix, may be polymer. Earlier, various types of fibers, such as glass fiber and carbon fiber, were commonly used for reinforcement.[5] But recently, there has been growing research interest in the use of natural fiber as reinforcement. In addition, natural fibers offer advantages such as availability, biodegradability, low cost, light weight, inexpensive, interesting physical and mechanical properties (high specific stiffness, low density and relatively high processing flexibility and good strength). As a result, natural fiber-based composites have been becoming more attractive for use as construction and structural element in building.[6]

The progress or trends of technology can be inferred from patenting trends where patent rights are considered as one form incentive to protect and promote investment in specific technology domain. The published patent applications and the granted patents provide both technical and

[3] Hao Wang, Pen-Chi Chiang, Yanpeng Cai, Chunhui Li, Xuan Wang, Tse-Lun Chen, Shiming Wei and Qian Huang, "Application of wall and insulation material on green building: A review," MDPI-Sustainability, 18 September 2018.
[4] C. Elanchezhian, B. Vijaya Ramnath, G. Ramakrishnan, M. Rajendrakumar, V. Naveenkumar, M.K. Saravanakumar, "Review on mechanical properties of natural fiber composites," Materials Today: Proceedings 5 (2018) 1785–1790.
[5] Xue Li, Lope G. Tabil, Satyanarayan Panigrahi, "Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites: A Review," journal of polymers and the environment, Vol.-15,4th January 2007.
[6] M.F.M. Alkbir,S.M. Sapuan, A.A. Nuraini, M.R. Ishak," Fibre properties and crashworthiness parameters of natural fibre-reinforced composite structure: A literature review" Composite Structure, volume 148, 15 July 2016,pages 59-73.Elsevier.

legal information which benefits many areas of business. The objective of this research paper is to analyze patenting trends in fiber-reinforced material as green building materials.

In order to understand the concept of green building, it is necessary to briefly examine the green building rating system.

1.1. GREEN RATING SYSTEM FOR BUILDING

Various green building rating systems have been developed to evaluate and promote the environmental performance of buildings and construction materials. Prominent rating systems include GRIHA and IGBC in India, LEED in the United States and internationally, BREEAM in the United Kingdom and internationally, and EDGE developed by the International Finance Corporation.[7]

The use of natural and renewable materials, such as jute, hemp, bamboo, coir, and other plant-based fibers, can contribute to the sustainability of green buildings by reducing dependence on non-renewable resources, minimizing embodied energy, promoting the utilization of agricultural residues, and potentially reducing environmental impacts. The integration of natural fiber-based materials into building components can support the achievement of credits or performance criteria under green building rating systems.

1.2. CLASSIFICATION

Natural fibers are mostly classified into animal fibers, mineral fibers and plant fibers.[8] There are numerous plants fibers, such as hemp, kenaf, jute, wheat straw, sisal, abaca, pineapple, cotton, rice husk, coir, ramie, which are used as reinforcement fillers in composites. Based on reinforcement and origin, it is classified as follows;

[7] Aboli A. Ravikar, Deepa A. Joshi, Radhika Menon,"International Scenario of Certifications and Rating Systems for Green Buildings"ISSN: 2278-3075,9(3):1678-1683, January 2020

[8] Parnia Zakikhani, R. Zahari, M.T.H. Sultan, D.L. Majid, "Extraction and preparation of bamboo fibre-reinforced composites," Materials & design Vol 63, November 2014.

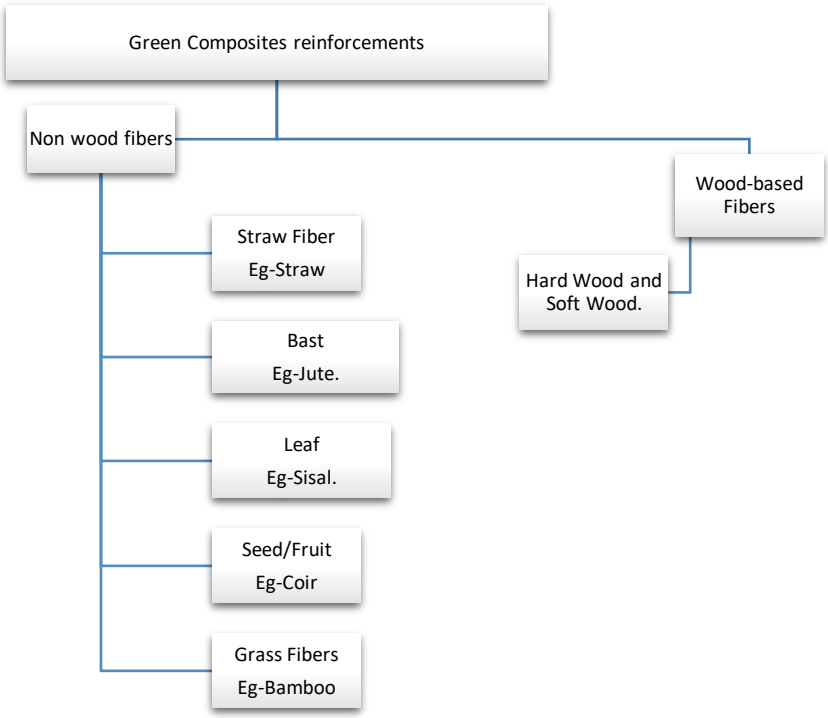

Fig. 1. Classification of natural fiber based on reinforcement[9]

The focus of the present work is on non-wood-based natural fibers such as bamboo, coconut, jute, sisal and straw. Wood fiber, animal fiber and mineral fibers are excluded from this study.

Table 1: Summarizes natural fibers characteristics, availability in the India and application in building material based on public domain materials.

Fiber	**Description**	**Qty in Mt/Yr.**	**Application in building material**
Bamboo fiber	Bamboo is extremely fast-growing grass. It offers particularly high tensile strength, crack resistance high stiffness, a rapid growth rate,	3.23	In structural concrete elements, lamination board, reinforced beam

[9] K N Bharath, Satyappa Basavarajappa, "Applications of biocomposite materials based on natural fibers from renewable resources: A review", Science and Engineering of Composite Materials, May2015 23(2)

	and its ability to fix atmospheric carbon dioxide		
Coconut fiber	Coir fiber is from the husk of coconut. It is coarse, strong and highly durable especially in wet conditions. Brown coir fibers are thicker, stronger and have high abrasion resistance.	11	It used in the production of lightweight panels, insulation boards, roofing components, bricks, blocks, mortar, plaster, and fiber-reinforced composites.
Jute fiber	Moderate tensile strength (stronger than coir and weaker than bamboo), low extensibility and good insulation properties are the key factors of jute fiber.	1.44	For making chip board, roofing sheets and door shutters
Sisal fiber	Sisal fibers are stiff fibers extracted from the leaves of the *Agave sisalana*. Sisal fiber as reinforcement improves tensile strength, crack resistance, impact resistance, and also provides good sound and thermal insulation properties.	.023(Asia)	For plastering of walls and for making precast blocks, ceiling boards, partition walls, roofing sheets
Straw fiber	Straw fiber is obtained from the dried stalks of cereal crops. Its high porosity justifies the use of straw fiber in the manufacture of materials for thermal insulation and impact resistance.	12.00	Manufacturing of roofing units and walls panels/board

Table 1 represents availability of natural fiber in India and its application as building materials.[10] It can be inferred that the production of natural fiber in India is quite high and it is

[10] Majid Ali "Review article Natural fibers as construction materials," Journal of Civil Engineering and Construction Technology Vol. 3(3), pp. 80-89, March 2012.

the second largest producer and consumer of the fibers in the world, next to China. In India more and more research works are in progress using natural fiber as composite material.[11]

1.3 Mechanical Properties

Natural fibers generally have low density, high tensile strength and flexibility. Further, chemical treatment can improve the mechanical properties. Factors that affect the mechanical properties are its geometry (diameter, length and shape, moisture absorption, wettability, swelling effect, fiber orientation, renewability and porosity).[12] One of the disadvantages of using natural fiber reinforcement is its hydrophilic nature along with hydrophobic nature of the matrix that deteriorates its mechanical strength. This shortcoming can be recovered by some chemical treatments and physical treatment by increasing the compatibility of natural fiber with matrix[13] .

Properties of some natural fibers and synthetic fibers[14]:

Fiber	*Density (g/cm^3)*	*Elongation at Break (%)*	*Tensile Strength (MPa)*	*Elastic Modulus (GPa)*
Bamboo	0.6-1.1	4-7	140-230	11-17
Coir	1.15-1.46	30	175	4-6
Jute	1.3-1.49	1.5-1.8	393-800	2055
Sisal	1.33-1.49	3-7	530-640	9-22
E-glass	2.5	3.4	3400	70

1.4 Natural Fiber in Concrete

[11] Praveen kumara J, Sunder Raj N, Chandan H R, Srivathsa Marathe, Madhu P, "Natural fibers and its composites for engineering applications: an overview," SARC International Conference paper, 3rd December 2017.
[12] Kin-tak Lau, Pui-yan Hung, Min-Hao Zhu, David Hui "Properties of natural fibre composites for structural engineering applications" Elsevier Composites Part-B -Engineering, Volume 136, 1 March 2018.
[13] Mohit Sood, Gaurav Dwivedi, "Effect of fiber treatment on flexural properties of natural fiber reinforced composites: A review," Egyptian Journal of Petroleum, 27 (2018) 775–783.
[14] C. Elanchezhian, B. Vijaya Ramnath, G. Ramakrishnan, M. Rajendrakumar, V. Naveenkumar, M.K. Saravanakumar, "Review on mechanical properties of natural fiber composites," Materials Today: Proceedings 5 (2018) 1785–1790.

Natural fiber is less prone to corrosion like steel fiber. The natural fibers when used as reinforcement, improve toughness of concrete and can reduce surface cracking through bridging action, leading to an increased impact resistance of the concrete.[15] Natural fiber is used in place of steel fiber reinforcement because it improves tensile strength. However, in addition to the drawback in using natural fiber with cementitious matrix is its durability which is decreased due to interface between the fibers with the cementitious matrix.

2. METHODOLOGY

Patenting trends have been analyzed based on the subscribed database QUESTEL version 1.9.8. It is used to retrieve and statistically analyze the patents of green building fiber reinforcement materials since the earlier to 2019 February. Search has been conducted using keyword/s. Field of search was "title, abstract and claim". Work involves identification of all the inactive and live patents and analyzing the patenting trends worldwide. Search query was generated by using one publication per family.

The following table shows the search flow by using database QUESTEL

Table 2. List of Search Strings Used in QUESTEL for Dataset Creation

Column	search term combination	field of search	country	period	no of hits
1	(bamboo fiber?) AND (fiber? D reinforce+) AND (building)	title, abstract and claims	All	All	46
2	(sisal) AND (fiber? D reinforce+) AND (building)	title, abstract and claims	All	All	49
3	(jute) AND (fiber? D reinforce+) AND (building)	title, abstract and claims	All	All	43
4	(straw fiber?) AND (fiber? D reinforce+) AND (building)	title, abstract and claims	All	All	21

[15] Aiswarya Sukumar, Elson John, "Fiber addition and its effect on concrete strength," (IJIRAE) Volume 1 Issue 8 (September 2014) www.ijirae.com.

5	(coconut fiber? OR coir) AND (fiber? D Reinforce+) AND (building)	title, abstract and claims	All	All	24

Non-wood base natural fiber that are used in reinforcement are straw fiber(straw), bast fiber(jute), leaf fiber(sisal), seed fiber(coir), and grass fiber(bamboo). Number of hits found from QUESTEL version 1.9.8 and these number of patents further refined by considering their relevancy for analysis

Bamboo-46 After screening no of relevant patent 42

Sisal-49 After screening no of relevant patent 47

Jute-43 After screening no of relevant patent 38

Straw-21 After screening no of relevant patent 21

Coconut-24 After screening no of relevant patent 23

It is observed that the ratio between published patent and granted patent changes year wise. Statistical analysis of top 10 IPC codes have been carried out. Based on application a patent portfolio map was prepared.

Limitations

- Patents that were not in the QUESTEL were not included. The search queries which are in description or full text were not included.
- The search for patent was performed in February 2019 hence patents published after this date will not be available in this deliverable.
- In order to understand the technology which were used in fiber reinforcement in green building we use technical keyword “fiber reinforce” for searching the patents. Because technology may be “fiber reinforced composite” (FRC), or may be “fiber reinforced concrete” depends on the material or process are used.

3. RESULT

In natural fiber reinforcement, renewable natural fiber such as hemp, sisal, jute, kenaf are used as reinforcement (as a filler) with polymer matrices or cement or concrete to obtain the

composite material or structure. Fibers are classified on the basis of reinforcement in two categories-non-wood based and wood fiber. The market dominance of non-wood fiber is due to widespread application of bast fibers. Non wood natural fibers are further classified according to use of different parts of the plant used such as bast fiber, seed/fruit fiber, leaf fiber, grass fiber and straw fibers.

A. Grass Fiber (Bamboo)

Analysis Based on IPC Classification

Table 2 represents top IPCs based patent applications filed in different national offices (including OFF and subsequent offices of filing). Top IPC classification in this technology is C08J-005/04 which describes Reinforcing macromolecular compounds with loose or coherent fibrous material. Other subsequent IPC classifications are C08L-097/02, C04B-016/02, B27N-003/04.

Table 3. Top International Patent Classification and description

IPC code	**Description**
C08J-005/04	Reinforcing macromolecular compounds with loose or coherent fibrous material
C08L-097/02	lignocellulosic materials
C04B-016/02	cellulosic materials
B27N-003/04	manufacturing substantially flat surface using fibers
B29B-011/16	comprising fillers or reinforcements
B29B-015/12	of reinforcements of indefinite length
B32B-037/10	characterized by the pressing technique, e.g. using direct action of vacuum or fluid pressure
C04B-028/10	Lime cements or magnesium oxide cements
C04B-028/14	containing calcium sulfate cements

Publication Trends

Figure 2 shows the patent publication trends of bamboo fiber reinforcement technology and legal status based on application priority.

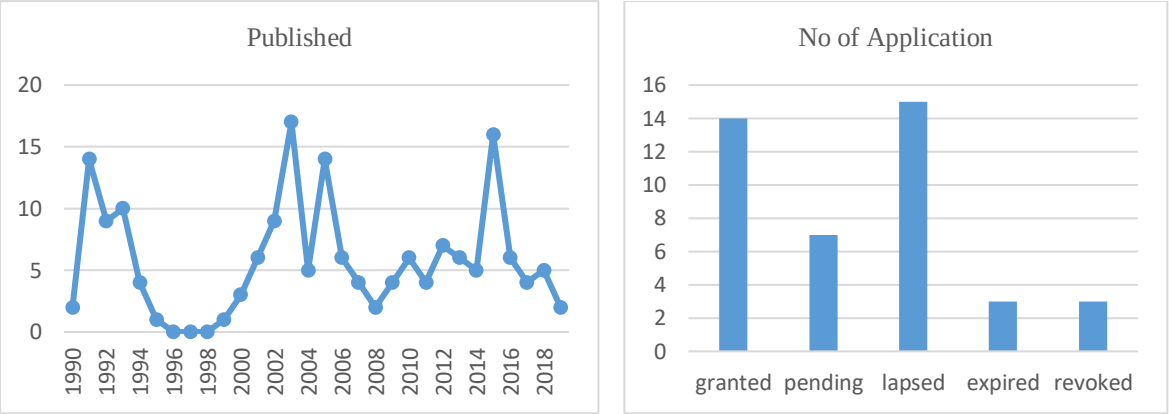

Fig. 2. Patent publication trend and legal status of bamboo fiber reinforced composite material

It is observed that bamboo has been used as reinforcement from earlier days. No steady trends are observed. Number of published patents in 2004 and 2016 is almost same. This indicates technology development trends are not being placed with time. No significant development is also observed. Figure 2 reflects that number of lapsed patents are maximum rather than the granted patents.

Application Priority

Figure 3 shows the priority application filed by country

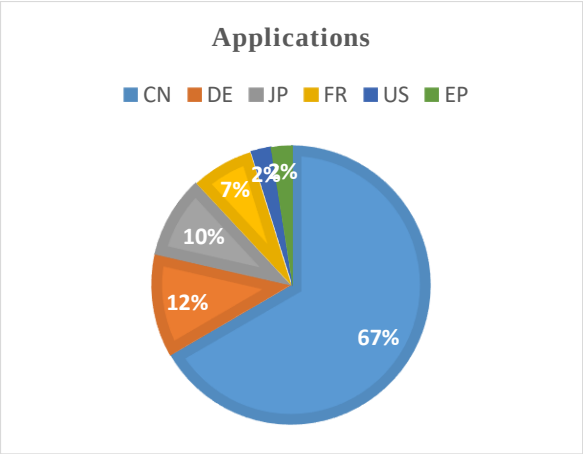

Fig. 3. Applications filed by priority country

From the figure 3, it is reflected that application is filed in maximum number in China based on application priority. After China, based on application priority Germany, Japan and France also have quite a number of patent filing applications.

Top Assignee

Figure 4 shows the top assignees in the bamboo fiber reinforcement technology

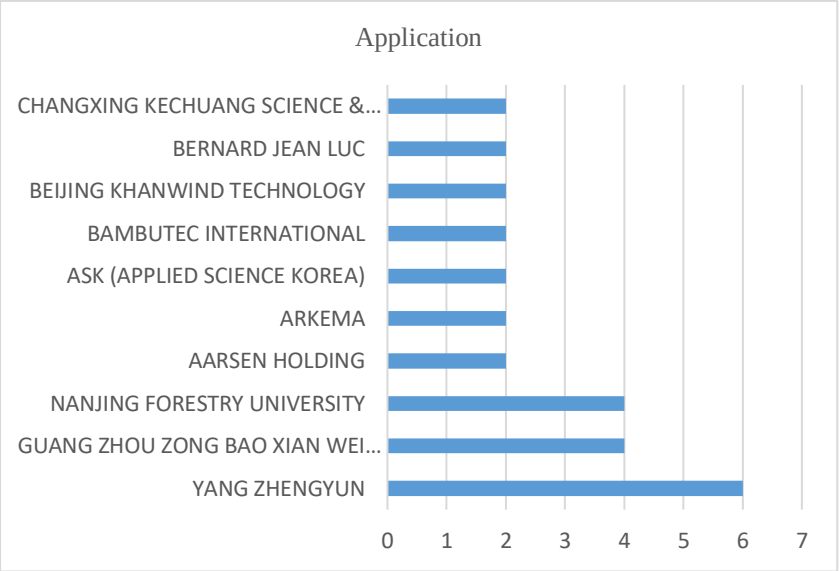

Fig. 4. Top 10 assignee in bamboo fiber reinforced technology

Figure 4 shows as such the top 10 market player in the bamboo fiber reinforced technology. It is observed that Yang Zhengyun is the top assignee followed by Guang Zhou Zong Bao Xian Wei Zhi Pin and Nanjing Forestry University.

B. Fruit Fiber (Coconut or Coir)

Analysis Based on IPC Classification

At IPC level 3 maximum patents fall in the C04B classification and further sub classified to the C04B-016/02-cellulosic material, C04B-014/18-perlite, C04B-018/08-flue dust, C04B-028/00-composition of mortars, concrete or artificial stone, containing inorganic binder or the reaction product of an inorganic and an organic binder. The table below contains top level 3 IPC classification and their description.

Table 4: Top International Patent Classification and description

IPC code	Description
C04B	lime, magnesia, slag, cements, compositions thereof, e.g. mortars, concrete or like building materials; artificial stone, ceramics, refractories, treatment of natural stone.
A01G	Horticulture; cultivation of vegetables, flowers, rice, fruit, vines, hops or seaweed; forestry; watering.
C08J	Working –up; general process of compounding; after-treatment not covered by subclasses C08B, C08C, C08F, C08G or C08H.
B29C	Shaping or joining of plastics; shaping of material in a plastic state, not otherwise provided for; after-treatment of the shaped products, e.g. repairing.
B32B	Layered products, i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form.

Publication Trend

Figure 5 shows the publication trend and legal status of the coconut fiber reinforced composite material used in building

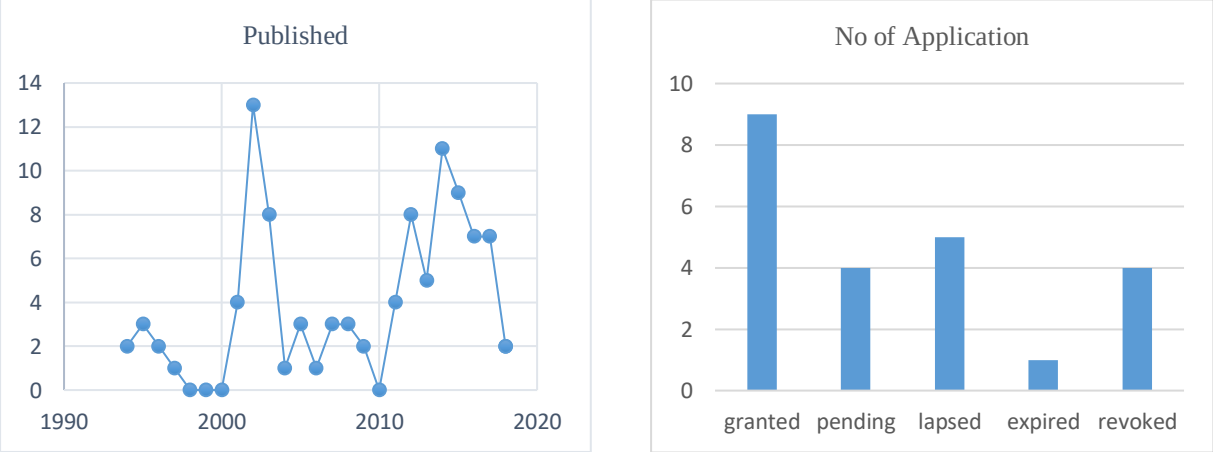

Fig. 5. Patent publication trend and legal status of the coconut fiber reinforced composite material

Figure 5 indicates that the applications are published including all patent families since 1994 but in 2002 and 2014 it rises its peak and there is a time break period from1998 to 2000 when patent application publication is nil in coconut fiber reinforcement technology. It can be inferred that the coconut fiber reinforcement used in green building is a developing trend as number of granted patents are more than lapsed patent, revoked patents and expired patents. It can be postulated that using coconut fiber in reinforcement technology and subsequent technology protection by patent filing will be more fruitful.

Application Priority

Figure 6 shows the patent application prior filed by which country

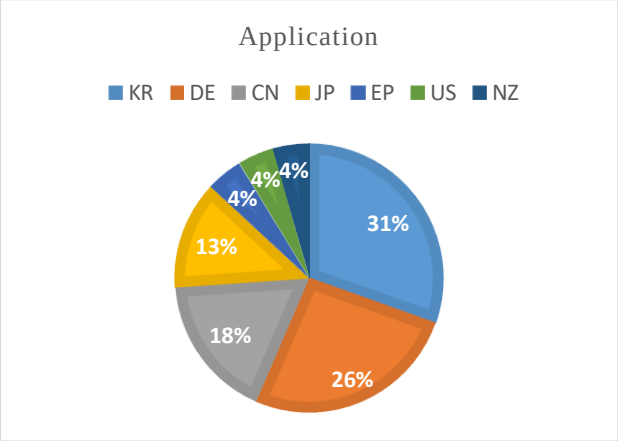

Fig. 6. Applications filed by priority country

Maximum patent First filing office in this technology is Korea followed by Germany, China and Japan.

Top ***Assignee***

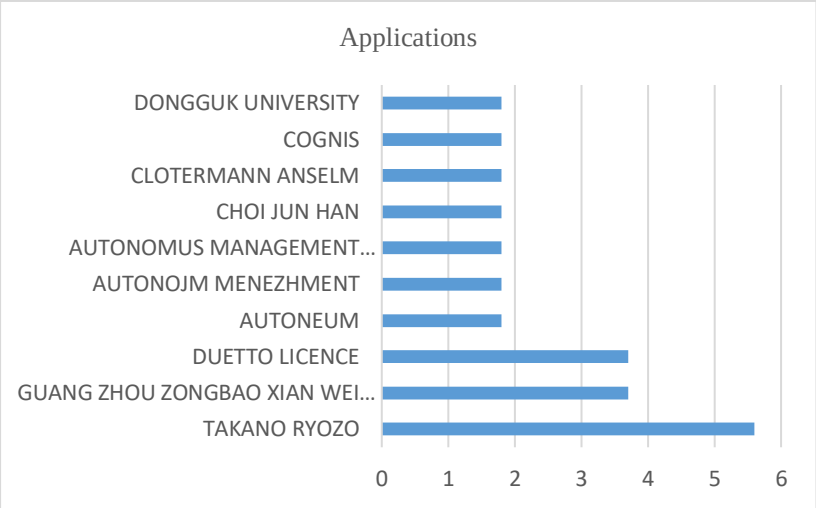

Fig. 7. Top 10 assignee in coconut/coir fiber reinforced technology

Figure 7 shows that Takano Ryozo from Japan is the top assignee in this coconut fiber reinforced technology followed by Guang Zhou Zongbao Xian Wei Zhi Pin from the US.

C. Bast Fiber (Jute Fiber)

Analysis Based on IPC Classification

Table 8 shows that IPC classification C08J is the top in this technology. Further subdivided to level 5 of this technology C08J005/04 and C08J005/24 are the top IPC classification. C08J005/04-reinforcing macromolecular compounds with loose or coherent fibrous material. C08J005/24-impregnating materials with prepolymers which can be polymerized.

Table 5: Top International Patent Classification and description

IPC code	Description
C08J	Working –up; general process of compounding; after-treatment not covered by subclasses C08B, C08C, C08F, C08G or C08H.
C08L	Compositions of macromolecular compounds.
B29C	Shaping or joining of plastics; shaping of material in a plastic state, not otherwise provided for; after-treatment of the shaped products, e.g. repairing.

B32B	Layered products, i.e. products built up of strata of flat or non-flat, e.g. cellular or honeycomb, form.
C08G	Macromolecular compounds obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds.
E04C	Structural elements; building materials.
B28B	Shaping clay or other ceramic compositions; shaping slag; shaping mixtures containing cementitious material, e.g. plaster.
B29B	Preparation or pretreatment of the material to be shaped; making granules or performs; recovery of plastics or other constituents of waste material containing plastics.

Publication Trend

Figure 8 shows publication trend and legal status of the jute fiber reinforced composite material used in building

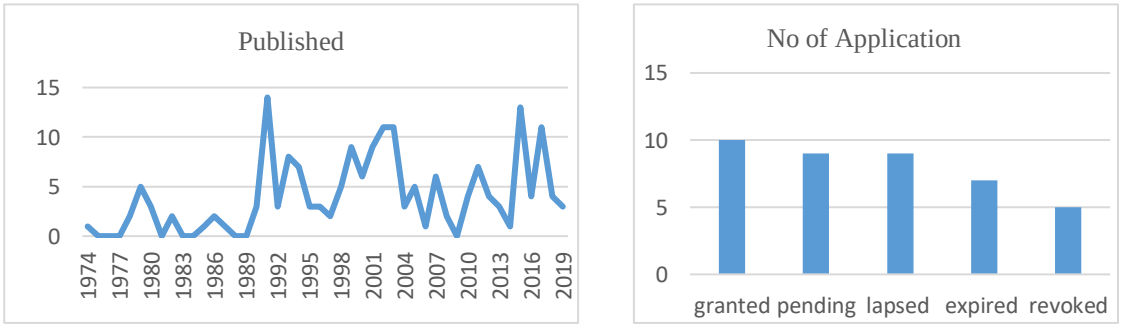

Fig. 8. Patent publication trend and legal status of the jute fiber reinforced composite

It is observed that technology is used earliest time. There is a technology gap between 75 to 77 when patent application publication is nil and after that publication is not yearly. It is inferred from the figure 8 that in 1990, 2002, 2003, 2015, 2017 numbers of publishing were in quite a good number. It is further growing from 2015 can say that using jute in reinforcement is emerging trends and in near future this technology has more scope. It can be said that the publication of patent is from 1974 to 2019 and sometimes it peaks and sometime decline but overall, average filing and publication of patent has been growing. It is the most ancient

technology in respect to other fibers reinforcement technology. Figure 8 shows that the numbers of granted patent, pending patent, lapsed patent, expired patent and revoked patent are almost same and the number of active patents and inactive patents are equal.

Application Priority

Figure 9 shows the application filed by priority country

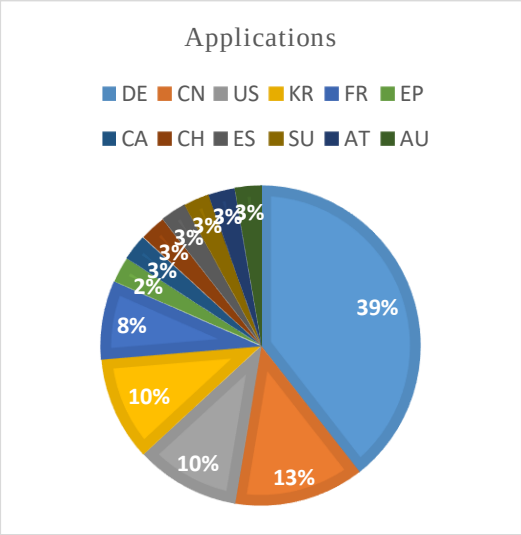

Fig. 9. Applications filed by priority country

Based on Priority application Germany is the highest first filing country followed by China, US and Korea. From the figure we get information that in jute fiber reinforcement the number of first filing countries for filing the patents is maximum than others fiber reinforcement technology.

Top Assignee

Figure 10 shows the top assignees in the jute fiber reinforced technology

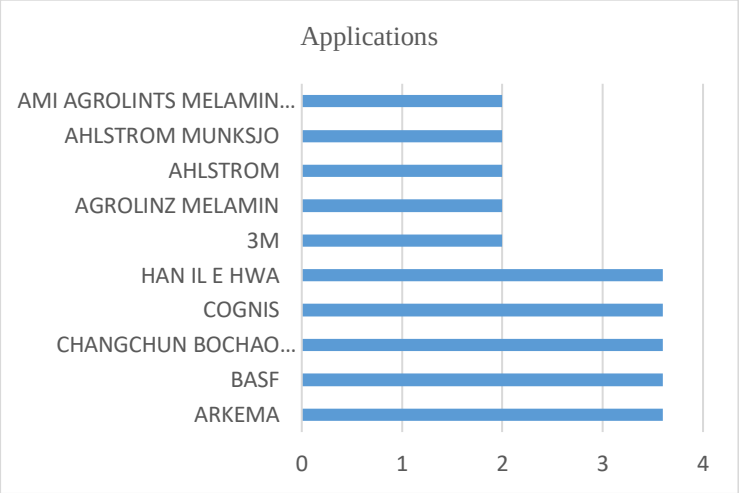

Fig. 10. Top 10 assignee in jute fiber reinforced technology

Figure 10 shows that top assignee in this technology are Arkema, Cognis, HAN IL E HWA, and BASF. These four assignees have equal numbers of patents assignment.

D. Leaf Fiber (Sisal Fiber)

Analysis Based on IPC Classification

IPC classification C08J-005/04 is the top in this technology followed by C08L-097/02, B32B-005/28, C08J-005/24.

Table 6: Top International Patent Classification and description

IPC code	Description
C08J-005/04	Reinforcing macromolecular compounds with loose or coherent fibrous materials
C08L-097/02	Lignocellulosic materials e.g. wood, straw or bagasse
B32B-005/28	impregnated with or embedded in a plastic substance
C08J-005/24	impregnating material with prepolymers which can be polymerised in situ, e.g. manufacture of prepregs.
B29B-015/12	of reinforcements of indefinite length
B29C-070/20	oriented in a single direction, e.g. roving or other parallel fibers.

C08G-059/34	obtained by epoxidation of an unsaturated polymer
C08K-005/00	Use of organic ingredients

Publication Trends

Figure 11 shows the publication trend and legal status of the parent application of the sisal fiber reinforced composite building material.

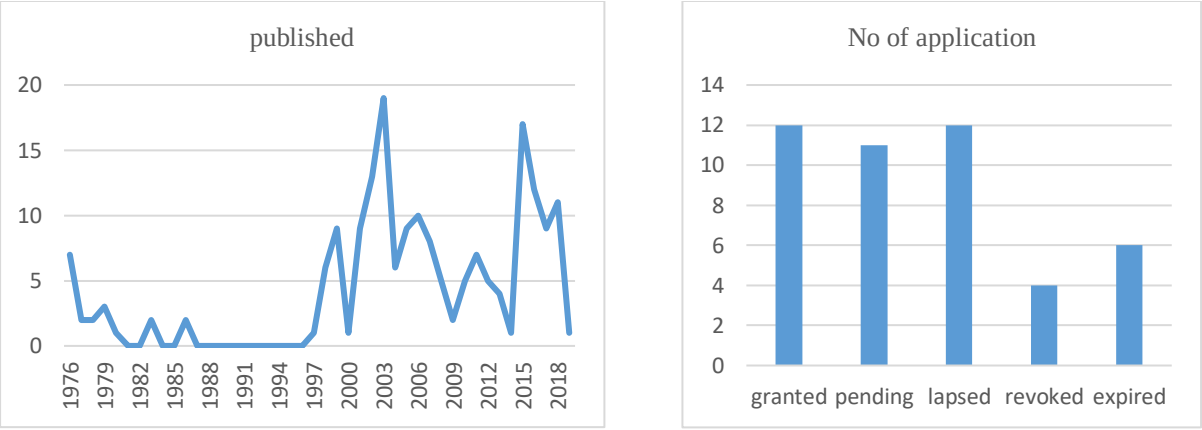

Fig. 11. Patent publication trends and legal status of sisal fiber reinforced composite material.

Though the patent on sisal fiber reinforcement technology first published in 1960 [US2950576][16] but after that the filing trend was decreased (by observing the sag curve). From figure 11, it is observed that from 1976 there is a trend for filing the patents. Total patent applications filed are 45 where 12 are granted and active. Number of granted patents and lapsed patents are in equal numbers. Many patents are pending for examination. So, the technology is in rising trends perhaps the filing trend is from very beginning because the sisal fiber used as reinforcement is mostly acceptable in this field. In near future it will have a wider prospect.

Application Priority

Figure 12 shows the number of priority applications filed by country.

[16] www. Patents.google.com [US2950576] Shock absorbing connections for building constructions

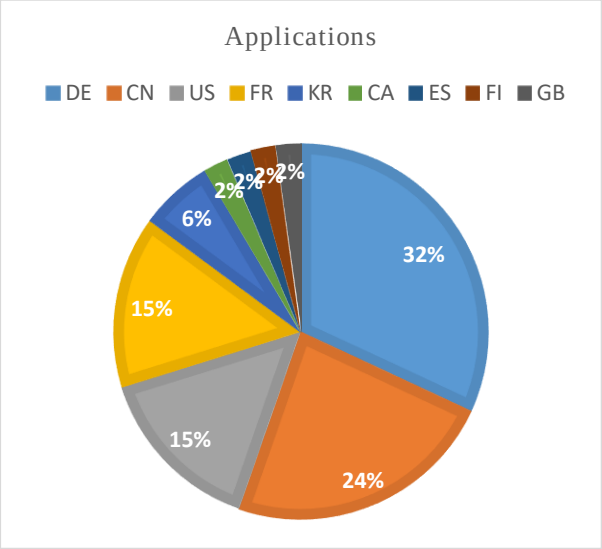

Fig. 12. Applications filed by priority country

From the figure 12, it is observed that most patent filing priority country in sisal fiber reinforce technology is Germany followed by China, US, France and Korea.

Top Assignee

Figure 13 shows the top assignees in sisal fiber reinforced technology

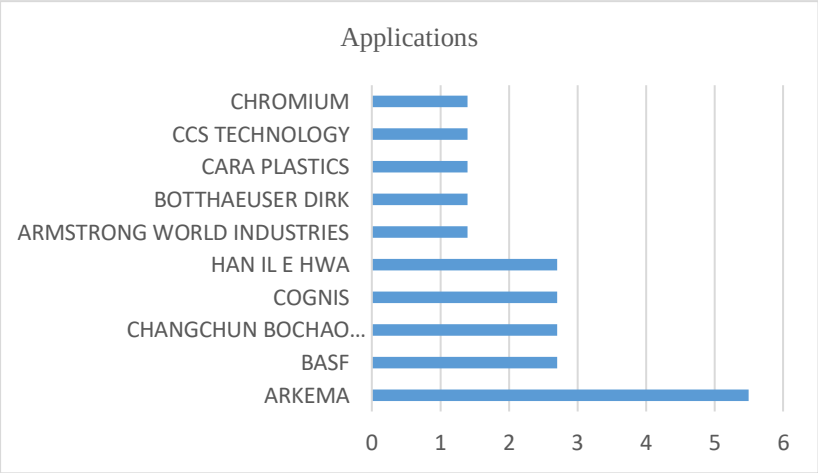

Fig. 13. Top 10 assignee in sisal fiber reinforced technology

Top assignee in sisal fiber technology is also same as jute fiber technology. Top 4 assignee in the sisal fiber reinforced technology are same as Arkema, BASF, Changchun Bochao Automobile Parts, Cognis. Top assignee in this technology is Arkema

E. Straw Fiber (Straw Fiber)

Analysis Based on IPC Classification

E04C-002/38 is the top IPC classification in the straw fiber reinforced technology followed by C04B-018/24, E04C-002/288, E04C-002/30 Description of all top 10 classification are mentioned in the table 7.

Table 7: Top International Patent Classification and description

IPC classification	Description
E04C-002/38	With attached ribs, flanges, or the like, e.g. framed panels (concerned with attaching to other panels or elements to form a structure, see the places for the relevant structure, e.g. E04B 2/00)
C04B-018/24	Vegetable refuse, e.g. rice husks, maize-ear refuse; Cellulosic material, e.g. paper.
E04C-002/288	composed of insulating material and non-metallic or unspecified sheet-material
E04C-002/30	characterized by the shape or structure
C04B-028/14	containing calcium sulfate cements
E04C-002/04	of concrete or other stone-like material of asbestos cement
E04C-002/06	Reinforced
C08L-097/02	Lignocellulosic material e.g. wood, straw, bagasse
E04B-005/04	with beams of concrete or other stone-like material e.g. asbestos cement
E04C-002/34	composed of two or more spaced sheet-like parts

Publication Trends

Figure 14 shows the publication trends and legal status of the straw fiber reinforced composite material used in building

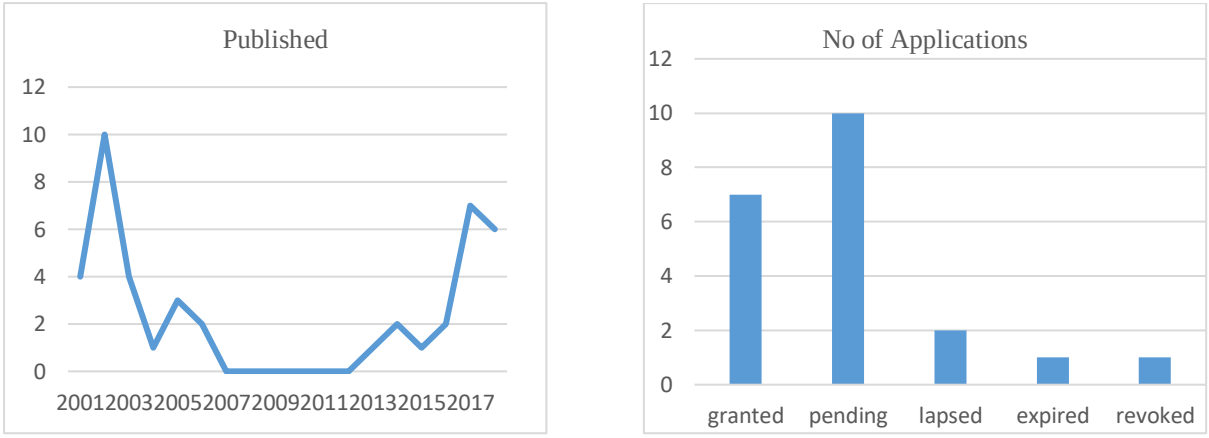

Fig. 14. Patent publication trend and legal status of the straw fiber reinforced composite

It can be assessed that first filing of the patent is not from a very early stage, it is from 1999. Germany is the first filing office and published in 2001. After that all the applications are filed by China. In 2002 more applications are published (10), followed by 2017 (7) and 2018 (6). Some of the filed applications in 2017 are granted and some of them are in pending status. After 2002 the application filing decreased and in 2007 to 2012 publication of patent applications are nil. From figure 14, it is observed that number of pending patents is more than granted patents. Lapsed, expired or revoked patents. The patenting trend in straw fiber reinforcement technology is most recent. The pending applications are in maximum number which are in due for examination filed in 2017 or 2018.

Application Priority

Figure 15 shows the priority applications filed by which country

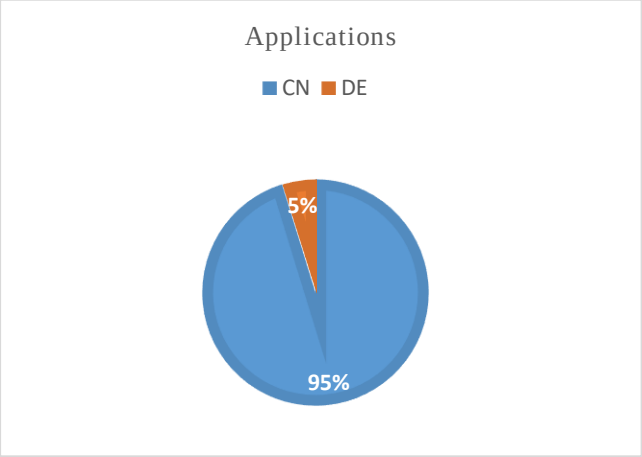

Fig. 15. Applications filed by priority country

In straw fiber reinforcement most of the patent filed by China.

Top Assignee

Figure 16 shows the top assignees in the straw fiber reinforced technology

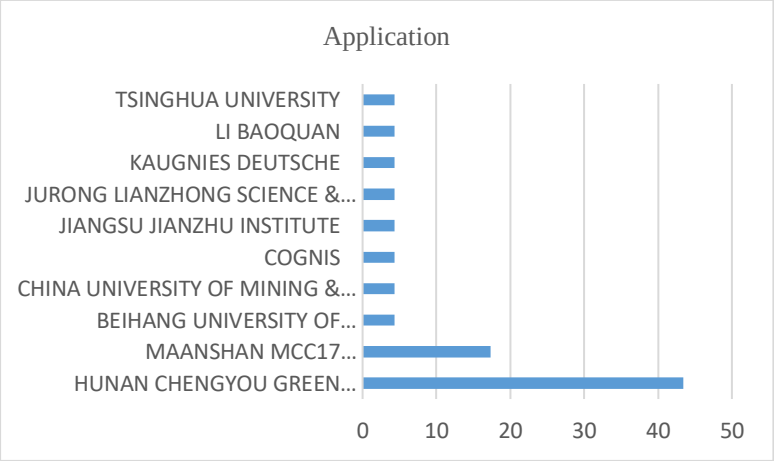

Fig. 16. Top 10 assignee in straw fiber reinforced technology,

It is well known that straw is used in buildings from ancient time but here the patent application filing in straw fiber used as reinforcement in building is from 2001 according to our search string. Hunan Chengyou Green Building Materials Technology (43.43%) is the top assignee followed by Maanshan MCC17 Engineering Science & Technology (17.35%). The assignees are from China.

4. ANALYSIS

Result indicates that patent filing based on IPC classification are more or less common to all of these five fiber reinforcement technologies. It can be assumed that Jute as reinforcement is

very old but straw fiber used as reinforcement is from early days, but patenting trend is very new. It can be said that fiber reinforced composite patent filing and publication has been growing from 2000 onwards. Cognis is the assignee who has the assignment in four of the above fiber reinforced technology like sisal, jute straw and coir fiber. Other important assignees in this field are Arkema, Changchun Bochao Automobile Parts who have more assignments in different fiber reinforcement technology.

4.1. COUNTRY SPECIFIC CASE STUDY

Analyzing country wise priority application, it is found that China, Germany, U.S, Korea, France are the most patent filing country, though the annual production of the natural fiber is 7.5 million tons in India as compared to worldwide production of 32-35 million tons[17]. Trends in patenting are growing in importance. It is observed from sharp rise in publication of the patent documents and granted patent in recent years. This trend highlights academic and industrial interest in this field and overall increasing commercial value. After year 2000, the number of publications and patents rose significantly in China.[18]

Figure 17 shows the IPC level 3 classification of the patents in China.

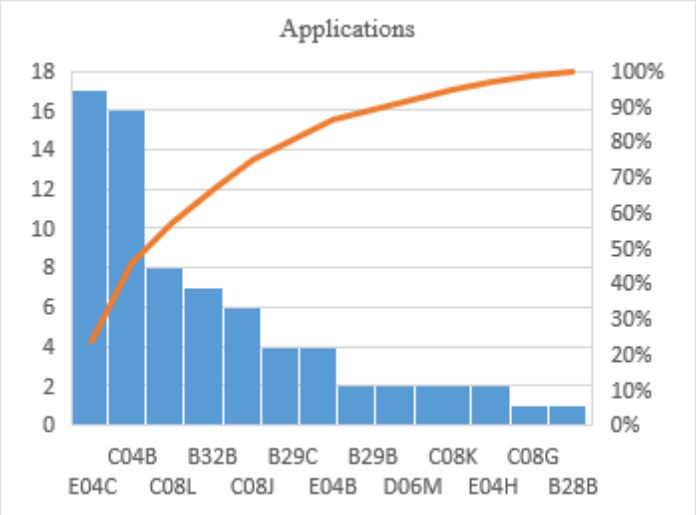

Fig. 17. Top 3 level IPC in specific country China

By collecting and observing the data from figure 17, IPC 3 level it can be said that, the top IPC is **E04C** followed by **C04B, C08L, B32B** and so on.

[17] https://unctad.org/publication/trends-natural-and-man-made-fibres-trade
[18] Ying Zhang, Jian Kang and Hong Jin, "A Review of Green Building Development in China from the Perspective of Energy Saving," MDPI-Energies, 2nd February 2018.

Description of the **E04C** - structural elements; building materials,

C04B - lime; magnesia; slag; cements; compositions thereof, e.g. mortars, concrete or like building materials; artificial stone; ceramics; refractories; treatment of natural stone.

C08L - compositions of macromolecular compounds.

B32B - layered products i.e. products built-up of strata of flat or non-flat, e.g. cellular or honeycomb, form.

On the other hand, in India few of published patent applications are from below IPC classification:

B29B11/16 – comprising fillers or reinforcements.

B32B5/30 – one-layer comprising granules or powders.

B28B1/14 - by simple casting, the material being neither forcibly fed nor positively compacted.

5. CONCLUSIONS

Use of natural fiber as reinforcement are increasingly used as green building material because they offer environmental, economic and functional benefits. These composites are lightweight than conventional reinforcement materials and provide adequate strength and stiffness. Acoustic and thermal insulation property is good for the natural fiber. And from the It is observed that the China and Germany are the most patent filing country. But maximum Chinese patents in this technology are protected in their own country whereas Germany as priority country most of the PCT filing takes place for Germany. Cognis is the assignee who has the assignment in four of the above fiber reinforced technology like sisal, jute straw and coir fiber. And other important assignee in this field is Arkema who has more assignments in different fiber reinforcement technology. From the above-mentioned fiber sisal is mostly used as a reinforcement filler in building, possibly due to high hardness. The straw cement-based building materials have been developed more recently, and China is the more patent filing country in this technology. In India though the production of natural fiber is high, but patent filing trend is very low may be due to lack of significant research, policy intervention.