A Prospective/ Constraint Review of New Innovative or Revolutionary construction Practices in Context to Material/Fibers Use in Concrete

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Abstract : Modern construction is based not only on the adoption of traditional construction /material practices for the production of concrete and production of high performance concrete that possesses higher workability, strength and durability with the incorporation of new material/ admixture/chemicals is acceptable challenge by researchers/ design engineers/ constructors .The two primary objective/considerations of almost all type of constructions specifically in transportation structures are durability and strength . In past twenty years some cementious material obtained from industrial bye product/waste such as silica fume,ground granulated blast furnace slag, fly ash, metakaoline, calcined clay or shale, natural pozzolonas etc. has been widely recognised or adopted as ingredient of cement/concrete through blending of cement or admixture of concrete. Attempts are now being made for new innovative construction technology/materials which provides better realization visions to architect in making more daring structure in context to strength and durability. This paper basically reviews the merits/demerits of revolutionary construction materials/techniques developed so for and supplemented with the experimental/statistical investigation on four types of natural fibers i.e. banana, coconut (coir), pineapple and jute fibers in context to it's use as concrete admixture on the basis of slump, compressive ,tensile and flexural strength of concrete tests to enable the produced concrete the greater resistance against cracking and spalling.

***Index Terms* - Self-Healing Concrete, Hydro ceramics, Natural Fibers, Translucent Wood, Grapheme.**

I. INTRODUCTION

Use of natural/renewable source of energy as reinforcement in concrete roof structures is one of the recent developments in the form of green approach to reduce/replace environmentally unfriendly material like steel through agricultural products/waste fibers, which have benefits of low cost/thermal conductivity/weight ratio, non-corrosiveness, recyclable and in frequent earthquake regions where infra structure damages are common and more repairs are required. Two long time strategic considerations behind the use/development suiting to Indian conditions are depletion of forest resources and insurance of good economic returns from agricultural /fruit wastes.

Normal unreinforced concrete generally contains numerous micro cracks which get widened under the applied load/stresses due to brittle nature, low tensile, flexural and impact resistance of concrete. To avoid the concrete brittle nature/low strength or durability, which cannot be neglected, is changed into ductile concrete through the incorporation of fibers in a randomly distributed manner and solving the problem of workability by addition of super plasticizers as the ductility characteristics plays an important role in the performance of concrete.

These fibers are used to reduce the shrinkage cracking/bridge the gaps through increasing the concrete ductility, resistance against impact, post-performance of concrete , plastic /drying shrinkage control and lowering the permeability/bleeding of concrete matrix. Besides the application of fiber reinforced concrete at small scale as compared to overall production of concrete, these natural fibers may be locally available all over the world as agricultural production/waste and fulfil the purpose of low sustainable building material as per requirement of social ,economic and environmental issues of modern society due to benefits of low cost/density/,health hazard, sufficient stiffness/flexibility as these fibers are disposable, renewable and biodegradable.

II. ANNALYTICAL/LITERATURE REVIEW OF INNOVATIVE MATERIALS

The aggressive and intense developments in the field of producing concrete and new innovative construction materials is gaining momentum all over the world with the use of digital technology, virtual &augmented reality, drones and project management. The floating piers made of polythene cubes of high density wrapped with one lakh square meter of yellow cloth as a

3km long pedestrian street of Sulzano in Italy is masterpiece example of great innovation in modern construction through utilization of available resources/waste derived materials. The different construction materials & technology that is responsible for the revolution in building construction sector may be broadly classified in four categories (shown in fig.1) as follows:

(a)Performance/specific characteristic materials

(b)Utilization of available resources / Waste derived Materials

(c)New Innovative Materials

(d)New construction expediting /control/monitoring techniques

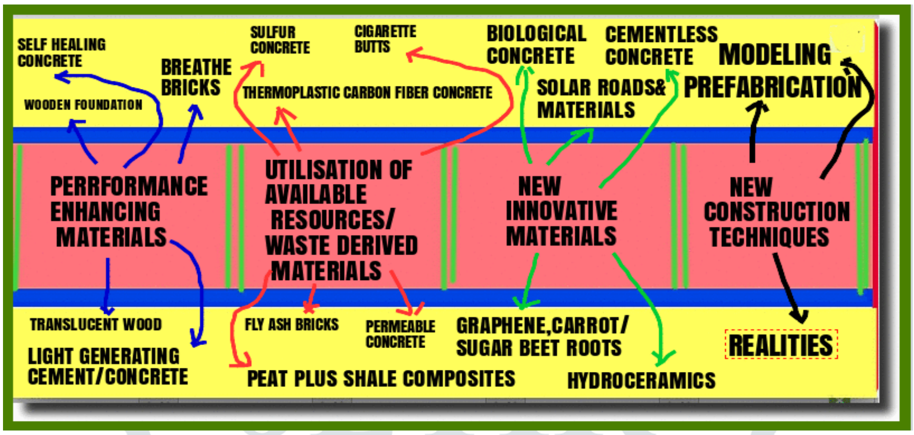

Fig1-Construction Materials & Technology Responsible For Revolutionary Building Construction

2.1. Performance /Specific characteristic materials

However division between performance and specific characteristic material is not possible but in general sense the recent developed material on the basis of specific characteristics are breathe bricks,translucent wood and,wooden foundation whereas self healing concrete, light generating cement/ concrete are performance based materials

2.1.1-Self Healing Concrete

It is produced either by the use of Spore-forming and alkali-resistant bacteria or by shape forming polymer. In later case auto genius healing takes place. For healing of cracks on the surface of concrete structures,the principle of biologically produced limestone is used and special type of bacteria genius Bacillus along with calcium based nutrients(calcium lactate,nitrogen &phosphorus) are added during the concrete mixing. These self healing agents are able to lie inactive in concrete even beyond the expected life of concrete itself say 200 years. On development of cracks and seeping water with crack brings the calcium lactate with the contact of bacteria which becomes active and produce insoluble lime stone which solidifies on the cracked surface. Precautions should be taken at the time of mixing of concrete that the self healing agents are not activated during the process of mixing. To avoid this self healing agents may be introduced in the concrete mix in the form of water permeable capsules. Presence of water is necessary for this process. The self healing agents introduced in clay pallets occupy about 20-25%volume of aggregates thus reducing the content of harder aggregates and subsequent reduction in compression strength.The cost of self healing concrete is almost double that of the conventional concrete

2.1.2. Light Generating Cement/concrete

The light generating cement is obtained by poly condensation of industrial waste, alkali, silica, water and sand at room temperature. The production process does not require high energy consumption and also the pollution is too low as compared to cement production. The Light generating concrete has good light transmitting property depending upon the ratio of optical fiber used to volume of concrete produced. Best architectural appearance, improved light condition with appropriate intensity and Optical fiber as additional reinforcement for the concrete are the remarkable benefits of it.

2.1.3. Breathe Bricks

To avoid the adverse effect of environmental polluted air on the health of living people the recent development of a system which allows/forces the filtered air inside the room plays an important role in context to indoor air quality. This system utilizes the bricks funnel on the outside of the building of the air entering the space through filtering and dropping of heavier particles present in the air down in the hopper and clean air either passively or mechanically is pulled inside through internal cyclone filtration system .To get indoor better air quality removal of heavy particles periodically is essential/ must. This system efficiency in context to fine & coarse aggregate are almost 40 and 100 percent respectively.

Breathe bricks also called pollution absorbing bricks forming apart of building consisting of double layer facade of the specialist bricks with insulating material inside. These bricks function like vacuum cleaner as outer surface absorbs fine and coarse pollutants of the air up to the extent of thirty percent &hundred percent respectively and center portion works as cyclonic filter separating the heavy pollutant particles enabling the removal of the same.

2.1.4. Translucent Wood

The translucent wood is created through removing the lignin from a wood veneer resulting it to become white /porous veneer, which is then impregnated with a transparent polymer matching with the optical properties of the individual wood cells. For removing/stripping the colour and chemicals the wood is placed in a boiling bath of water with chemicals and sodium hydroxide until the colour of wood becomes white and then soaked with epoxy which provides the sufficient strength and clear wood looking like plastics. The benefits of translucent wood are low cost easily available/ renewable material used as solar cells, providing more strength/insulation than glass and less biodegradable and more eco-friendly than plastics.

2.1.5. Wooden Foundation

Besides fulfilling the requirements of good foundation i.e. keeping the basement or crawl space dry, support the load of the structure and protection against heat loss the wooden foundation ,which are cheaper(both material &cost),easier to wire,better insulation &energy efficient, lighter, more elastic and more crack resistance than concrete, were short term choice as compared to commonly /widely adopted concrete foundations on the grounds of stronger material, more moisture resistant and life span, no toxic salts chemicals presence due to treatment of wood and wider shape pattern than wood in the past. The things are now changed and wooden foundation is gaining superiority over concrete foundation and becoming common building practice due to benefits of quick building, easier modification, less moisture absorption of treated wood and quick drying ability over a conventional concrete in locations where sufficient availability of wood exists.

Though the use of wood in house building & bridges right from the beginning of development of human civilization/search for shelter from moving out of caves but in modern times it was supplemented by other building materials concrete &steel suitable for tall buildings and it's use was limited to window/doors and interior decoration on account of weaker material and vulnerability to fire than other materials. With the introduction of mass timbering tric consisting of several types of laminated timbers either gluing together pieces of lumber to create strong beams or pieces of lumber stacked in alternate direction to form panels. Mass timbering techniques not only removes both the limitations of its use in modern house building as the strong beams and panels are able to bear the higher load and it becomes fire resistant due to creation of char when burning by outer layer which supports the insulation of the rest wood but also supports sustainable forestry resuling the capturing of carbon due to tree growth and averting global emissions up to the extent of 15-25 percent subjected to the return to the past i.e. replacing building/bridges construction materials with wood.

2.2-Utilization of Available Resources / Waste Derived Materials:

Millions tons of non-recycled waste produced each year and its recycling involve energy consumption and cause pollution problems. Waste collection, disposal and recycling is also imposing challenge almost in all the cities of India. Green concrete concept which is based on use of waste material as cement or aggregate substitute is developing very fast and may be regarded as characteristic feature of modern /recent concrete. The various characteristics of utilisation of available resources based or waste derived materials has been discussed in the following paragraphs.

2.2.1-Sulphur Concrete:

Sulphur concrete is produced by heating mixture of sulphur and aggregates in proprtion1:1 above the melting point of sulphur i. e.115^{0}C and cooling .Due to sufficient availability of sulphur (about 17 percent of the entire planet) and non-requirement of water in production of sulphur concrete, this has a bright prospective as building material for the construction of buildings on Mars and hence also known as martian concrete which differs from sulphur concrete as it reacts with the minerals in martian soils , produces strength two and half times more than ordinary concrete and heating temperature of sulphur as 240^{0}C.

2.2.2-Thermoplastic Carbon Fiber Concrete:

The thermoplastic carbon fiber composite developed in Japan known as CABKOMA strand rod is produced by carbon fiber covered with outer layer of synthetic and inorganic fibers finished by impregnation with thermoplastic resin. High tensile strength, strong body structure, lightest seismic resistant reinforcing material in the world and superb aesthetic quality are it's characteristic features .

2.2.3-Cigarette Butts :

Cigarette butts waste produced about twenty percent of cigarette produced(yearly expected production requirement /demand in the world is about 100 million in the year2025) containing arsenic, chromium,cadmium and nickel have the negative/harmful impact on environment through the entering of these materials in soil &water in slow manner as cigarette butt takes plenty of time i.e. many years to break down and leaching in soil and water due to poor biodegradability of the cellulose acetate filters. These waste butts mixed with clay are now utilized as the raw material for the manufacture of lighter bricks. These bricks are not only cleaner,cheaper and better insulator but also cut the energy requirement of heating and cooling of buildings made up of these bricks. Additional benefits of cigarette butt mixed clay bricks over clay bricks are that fuel energy /cost is reduced to 42 percent for firing and placing the butts into bricks prevents the chances of leaching /contamination of soil/water.

2.2.4-Fly Ash Bricks

Fly ash bricks is result of the prompted concern regarding the way to utilize the waste ash sitting in ponds posing serious ground water pollution and mountains of fly ash/air pollution due of fly ash under suspension produced by rapid progress/expansion of thermal power plants utilizing coal as fuel. These bricks have advantages over bricks in context to lighter weight enabling the convenience in use and cheaper production cost in addition to making low cost houses for serving the residential problems of fast growing population of the India.

2.2.5-Permeable Concrete

Permeable concrete ie use of larger stones and less sand thus containing almost 20 percent empty or void space without sacrificing the strength of concrete produced allows surface runoff/rainwater to pass through it without hindered is now adopted as common practice for urban roads inside the city to overcome the problem of runoff/drainage due to construction of roads and other inappropriate construction works. Besides this ,porous concrete ,the other name of permeable concrete is also useful in planning/design/management of city sewer system.

2.2.6-Peat Plus Shale Composite

In the locations where wetland or peat is available in sufficient quantity,the concrete like material can be produced by utilizing the milled peat ,oil shale ash as binder and nano- particles of silica at about only 15 percent cost of the building made with traditional building materials as the main materials utilized are locally available and has been used in the past for low cost housing on the ground of its cost ,strength, low weight & heat transfer ,durability and fireproof. It hardens about 24 hours of its application but retains its elastic quality for some time enable it to stack before use. Besides the cooling benefits ,the soundproof building construction may be achieved through the utilization of these materials in building construction.

2.3-New Innovative Materials

On the ground of lesson learnt from the past i.e. use of blood/ milk/marl in the historical duarable structure still surviving built during roman period,the search for new innovative materials is concentrated to fruit,vegetable/agricultural products and waste material utilisation responsible for the environmental problems. No doubt some of the materials considered today will be the futuristic/revolutionary building materials of tomorrow.

2.3.1-Biological Concrete

Biological concrete that supports natural, accelerated growth of pigments is manufactured with a magnesium phosphate cement which has been used as a repair material in the past and widely adopted in the medicines as bio-cement /dentistry due to quick setting,no additional impact on environment and non-requirement of reducing its PH value. It consists of four layers element i.e. structural layer, waterproofing layer, biological layer and discontinuous layer with a reverse waterproofing layer. It offers aesthetic /ornamental, environmental and thermal advantages due to its adaptability of faces/surfaces with different finishes and shades of colour. A hard bio-polymer also called myco form that is a made up of mushrooms, oat branches and wooden chips toughened by ganoderma lucidin surrounded by bacterial cellulose as external skin is gaining momentum for the use as substitute for furniture/ wood/ glass material in developed country due to its architectural superiority, creation in desired shapes/ sizes, compostable/ recoverable at the end of the useful product life cycle with low energy/ technology and pollution free.

2.3.2-Hydro Ceramics

Hydro ceramics as the name implies consists of hydro-gel as smart material and ceramic as supportive material combined with fabric as water channel. This composite material specific absorption/evaporation properties of hydro-gel and thermal mass/ humidity property of ceramics/fabric enable the building responsive with external temperature behaving like living entity as a part of nature/environment ultimately resulting the automatic cooling/heating of building depending upon environmental conditions i.e. sun shining and raining thus reducing the electricity consumption up to the extent of 30 percent as the hydro-gel is capable of absorbing/ evaporating/ retaining water 500 times of its own weight.

2.3.3-Cementless Concrete

The by-products from coal-fired power plants i. e. fly ash utilization for producing more environmentally friendly concrete suffers from the drawbacks that only small quantity of fly ash is consumed as admixture of cement and larger amounts of cement/sodium-based activators,which not only cancels out both the environmental and cost benefits thus defeating both the purposes of utilization of fly ash and reducing environmental pollution due to cement manufacturing. New advancement in this context is the development of cement less concrete/composite containing major part of fly ash(75% to 82%) and minor part of sodium based activator(5% to7%) and material containing calcium oxide and nano silica. Though this composite is able to gain seven days compressive strength similar to conventional concrete produced by cement but durability, time dependent long-term behavior, creep/shrinkage and other concrete performance tests are required before its adoption as substitute of conventional concrete.

2.3.4-Graphene, Carrot /Sugar Beet Roots

Graphene,the world's strongest man made and wonderful material in thick sheet form of one atom of linked carbon atoms is now being utilized for enhancement of produced concrete characteristics in terms of compressive strength (increase 2.5 times),flexural strength(2 times) and permeability(decrease up to the extent of twenty percent) through using water mix containing suspended flakes of graphene in place of normal water in concrete production. The benefits due to this lies in fact that:

(i)Due to increased strength concrete production less concrete pouring upto the extent of fifty percent of the material consumption(cement,coarse sand and stone grit) is required for obtaining desired strength and durability of concrete thus saving in production cost

(ii)Concrete produced is Eco-friendly&water resistant due to production requirement of less cement thus reduced almost fifty percent of carbon dioxide emission in the environment and reduced permeability respectively.

Recent advances in series of reduction of cement in concrete production without compromising the strength of concrete is the use of cellulose based platelets /sheets obtained from synthesizing of carrot/sugar beet roots. The adding of these platelets increase the calcium silicate hydrate/hydration rate which is primarily responsible for gaining the strength of concrete. In other words to achieve the desired strength of produced concrete less cement up to the extent of 80 percent per cubic meter as compared to production of normal concrete if the platelets are added enabling the less cement production/less carbon dioxide emission in the environment.

2.3.5-Solar Roads &Materials

Solar roads also called smart roads is the replacement of asphalt roads with solar panel of size 30cmx30cm interlocking panels having their own LED light. These roads may be considered as application of information/communication technology in the field of road transportation including traffic/mobility management of infrastructure, vehicles and users. Solar road consists of three layers i.e. road surface layer,electronic layer and base plate layer. Road surface layer has photo voltaic cells that are capable of generating electric power by attracting sun's rays/ converting solar radiations into direct current electricity. For proper&safe functioning of this layer the requirements of high strength through using toughened glass of hardness range 5.5-6measured on Mohs scale of hardness(much higher than presently used road materials),slide proofing by traction provision and water proofing arrangement are ensured. Electronic layer contains microprocessor boards containing heating elements of the panels enable the melting/heating control of the snow above the panels ultimately resulting the sensitiveness of the the weight on the panels, whereas the base layer collects/distributes solar energy converted electric power to homes, street lights, cars, battery and for any other purposes connected to solar roads. Though the adoption of these roads are few &limited i.e. First road in the world opened in 2016 only 1km section in Tourauvre, Orne, France and 1.2miles stretch of Jinan Solar Highway in china in 2017 due to higher initial cost or fund requirement, less research/knowhow in this field but this type of road have brighter prospective in future specially in India because of the availability of solar power throughout the year(almost300days),providing the solution of present problems of energy source, climate change, air pollution and road hazards.

2.4. New Construction Expediting /Control/Monitoring Techniques

The changes/progress in context to innovation in costruction has been noticed as slow since we rely on old traditional method used with the beginning of construction i.e.Roman times .This is perhaps due to variabilty in various project sites in context to location ,construction problems, weather , temperature, soil characteristic and ground water conditions. Project teamwork full commitment ,suitable material procurement, appropriate design ,quality control and monitoring requirement of incorporation of advanced technology enable it to implement at small scale and innovations in this regard get restricted or only small use. However the prefabrication, modelling and realities techniques with the advancement in field of computer science are developing very fast in last two decades.

2.4.1. Pre fabrication

Prefabrication is now gaining in popularity / momentum as timely completion of project by casting the building elements with well controlled environment in a factory before assembling it to the site at required location/position. As the element is prepared in a factory quality control and time management can be better managed with less worker and less cost as compared to traditional construction methods.

2.4.2. Modelling

Computer software for producing three dimensional mock-ups incorporating time and cost including the cost with different times for a planned civil engineering structure is available and widely adopted for building information modeling e. g. manipulation of various construction methods/materials/techniques.

2.4.3. Realities

Virtual/augmented reality enable to visualize seriousness of construction site hazards and safety measures by the learner/site worker thus ultimately resulting the safe working training/sites .VR /AR tied with BIM Software process assists the designer/contractor in context to decisions through virtual walk through of planned structure by providing more information of construction processes, saving time and costs of a structure much before its construction starting or during construction.

III. Comparative Analysis of Properties of Selected Fibers

On the basis of parts of the plant from where fibers are isolated ,natural fibers are classified into three categories i.e. fruit, stem(blast) and leaves fiber as shown in fig 2:

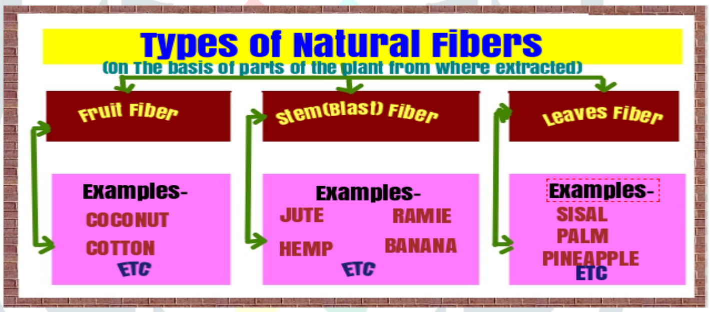

Fig2 - Classification of Natural Fibers

The four natural fibers i.e banana, coconut, pineapple and jute selected for study belong to different categories covering all types of fibers as shown in fig:3

Fig 3- Natural Fibers Selected For Study

The various parameters/characteristics measured /obtained as secondary data after the analysis of primary data of previous researches characteristics of different fibers selected for studies are shown in Table 1.

Table 1- Parameters/Properties of Selected Fiber

Particulars	Banana Fiber	Coconut Fiber	Pineapple Fiber	Jute Fiber
Diameter (µm)	120	250	80	200
Density(Kg/m^3)	1350	1140	1460	1430
Moisture Content(%)	12	10	18	8
Moisture Absorption(%)	130	66	78	140
Elongation At Break(%)	2.4	30	2.20	1.80
Young's Modulus(M Pa)	3.5	1.75	7.5	7.0
Fineness(%)	20	12	24	10

3.1-Diameter & Moisture Absorption (%)

For the discussion /comparative analysis parameters results selected were categorised in different diagrammatically presentation format on the basis of the value of result data range. First diagrammatic representation of diameter and moisture absorption are shown in fig 4.

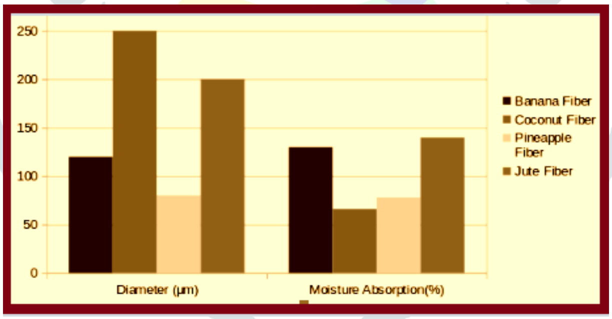

Fig 4- Diameter & Moisture Absorption (%) of Selected Fibers

As the natural fibers are locally availalbe material ,not only their length and diameter varies from place to place but also they are not uniform in length. The typical values of diameter for unprocessed different types of natural fiber shown in table vary from 80 (µm) for pineapple fiber to coconut fiber250(µm).For the length determination of fibers used in fiber reinforcing concrete a numerical parararameter aspect ratio (fiber length/equivalent fiber diameter) is deciding factor which is kept in between 30 to 150 with the size range of fiber from 25mm to50 mmas the too large/small size of fiber adversly affects the quality of concrete produced. Recent development in the context to providing secondary reinforcement in the form of natural fibers in addition to conventional rod reiforcement to overcome concrete weakness in tension and tendency to be brittle for achieving economy in construction is gaining momentum. The main difficulty to use these fibers occur due to relative higher moisture absorption resulting poor compatibilty between fiber and matrix. Hence the chemical treatment of fibers is an essential requirement for improving the surface properties, adhesion between the fiber & matrix and above all the reduction of moisture absorption of composites and strength of fibers.After cleaning banana fibers are immersed in 6% NaOH solution for2-4 hours at room temperature and passing/cleaning through water tank as well as flowing water. The filtered fiber is then dried before use. Coconut fibers are treated either 20% NaOH solution or$KMnO_4$ solution/H_2O_2 solution.The NaOH treatment leads to crystallization on the surface of the fiber, while the $KMnO_4$ treatment creates trench groove on the surface of coconut fiber result in improvement of bonding between the fibers and matrix.The chemicals used in the treatment of jute fibers used in fiber reinforced concrete are

Sodium Hydroxide (NaOH),Potassium Permangnate (KMnO4) solid and Acetone liquid.Pineapple leaf fibers mechanical properties are modified by combined diute alkai &polymer emulsion treatment.

3.2. Density of Different Fibers

The density of banana ,coconut ,pineapple and jute fibers are1350,1140,1460 and1430 Kg/m ^{3} respectively as shown in fig 5 shows almost the same density of each fiber which is in between 55-60 percent of concrete density. Therefore these fibers are very useful in production of light weight concrete.

Fig 5 - Density of Different Fibers

3.3. Moisture Content &Absorption Percentage

Both moisture content and fineness percentage of fibers as observed in Fig 6 contains same pattern with highest value of pineapple fiber and lowest value of jute fiber. The trend of obseved values for banana fiber is towards pineaple fiber whereas for coconut fiber it is towards jute fiber. Thus banana /pineapple fibers use can be given priority over coconut/jute fibers on this ground.

In concrete mix design which is generally carried out in cases of any admixture or new material is added to concrete as ingredient of concrete ,aggregate volumes are determined on the basis of oven dry unit weights but concrete produced at site is based on actual weights. Hence any moisture content in the ingredient will result an increase in its weight and almost all materials used in concrete production contain certain moisture and depending upon its surface condition of dry or wet ,it will absorb or give up water to the water mix during concreting resulting in the change in water cement ratio of the concrete produced. In other words net change in the amount of water in concrete mix takes place. The adjustment in amount of water mixed in concrete depending upon the natural/ absorption moisture content percentage and quantity of fiber used must be made before its use. Fineness of ingredient of concrete is responsible for the rate of gain of strength and evolution of heat ultimately resulting the rate of hydration as the fine particles offer greater surface area for hydration and faster development of strength /increase in drying shrinkage.

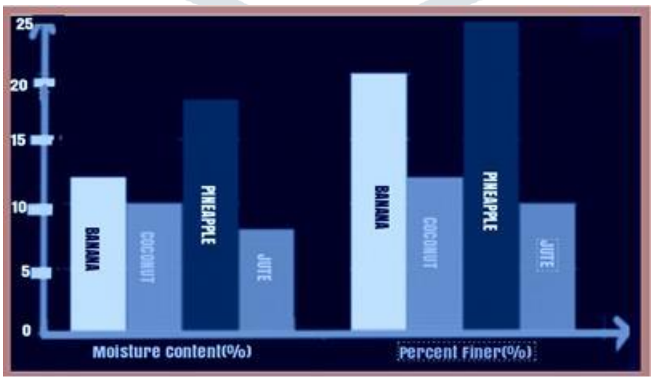

Fig 6- Moisture Content &Absorption Percentage of Four Fibers

3.4. Elongation at Break (%)

Elongation at break/fracture strain is measured in terms of ratio between changed length after breakage and original length expressed as percentage. This test is carried out for the determination of capability of natural plant fiber to resist changes in shape without crack deformation. The coconut fiber exceptionally show a higher value of elongation at break(30%)which gives the indication of lower strength and young's modulus whereas the other fibers taken /selected for study has this value almost in the same range. Chemical treatment of the fibers control/improve the elongation at break

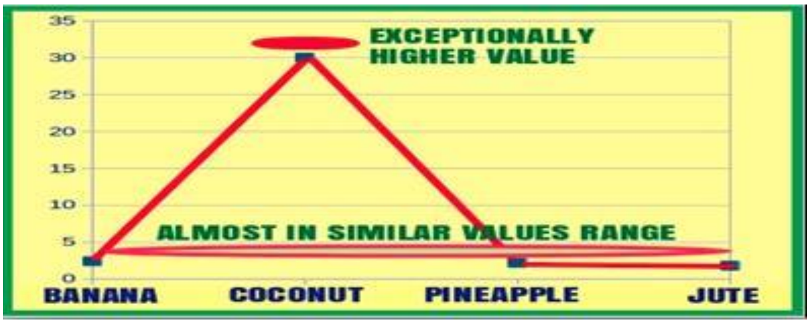

Fig7- Elongation at Break(%) of Various Fibers

3.5. Young's Modulus

The resistance of a material to the recoverable /elastic deformation is the measured by the young's modulus of elasticity. The material having higher young modulus are known as stiff material which changes their shapes only slightly under elastic loads and requires high loads to elastically deform whereas material having low yonng's modulus changes its shape considerably are called flexible material. On the basis of this Pineapple &jute fiber can be categorised as stiff, banana fiber in moderate category and coconut fiber as flexible as the value in case of banana fiber is half of the pineapple/jute fiber and 1/4th in case of coconut fiber observed in fig 8.Though the addition of coconut fibers in concrete eliminates the propagation & growth of cracks but its compressive strength improvement is not remarkable .However it is commonly adopted /used in durable roofing sheets/tiles production

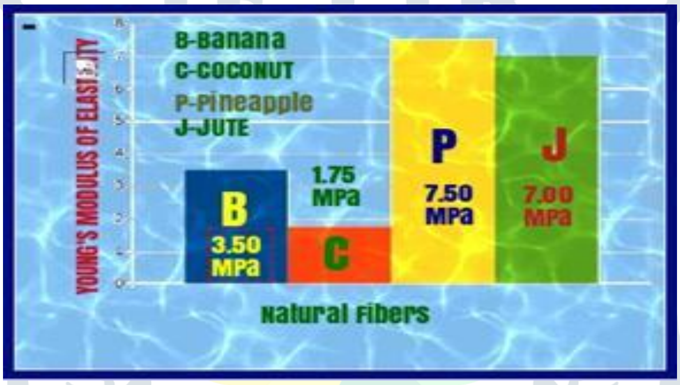

Fig 8-Young's Modulus of Banana, Coconut, Pineapple &Jute Fibers

IV. Experimental / Statistical Analysis

Experimental /statistical analysis consists of the following four steps:
Step I- Preparation/arrangement of fibers for test analysis
Step II- Identification of maximum percentage of fibers to be used
Step III- Selection/performance of tests
Step IV- Statistical analysis of test results

4.1. Preparation/Arrangement of Fibers

All the fibers used for the tests were arranged from the local village/ temple/ resident / commercial shops by cutting uniform length of fibers using cutting machine/scrapping machine containing various sizes of rollers . Each fibers was cleaned through immersion tank and flowing water ,sundried and dust removed befoe treatment if not treated earlier and also after the treatment .All the fibers were pre-soaked in water for 2to 16 hours depending upon the surface condition and water absorption. Ordinary portland cement 53 grade, fine aggregate of natural river /coarse sand and stone grit of size varying from 12-20mm were used. Concrete mix was designed as per ACI method for concrete grade M30 and water cement ratio 0.55.

4.2-Identication of Maximum Percentage of Fibers to Be Used

In the first stage of experimental investigation compressive strength tests on concrete specimen cubes of size 150mmx150mm x150mm casted and cured after 28 days with addition of banana fibers of each category i.e 1 to7 percent by mass of cement and without addition of fibers for determining the optimum percentage of banana fiber addition were carried out as per Indian standard testing procedure. The same procedure was repeated for coconut, pineapple and jute fibers. The length of the fibers were kept considering the aspect ratio in between 30 to 150 in between 25mm-50mm depending upon the equivalent diameter of the fiber. The test results are shown in table 2 to5.

Table2-Banana Fibered Concrete Compressive Strength (MPa)

Fiber(%)	Sample1	Sample2	Sample3	sample4	sample 5	Average
0	40.76	40.75	40.76	40.85	40.88	40.80
1	43.61	43.58	43.49	43.64	43.43	43.55
2	46.50	46.51	46.46	45.43	46.60	46.50
3	49.51	49.57	49.59	49.61	49.47	49.55
4	52.92	52.87	52.63	52.78	52.80	52.80
5	49.18	49.39	49.24	49.33	49.36	49.30
6	42.60	42.61	42.56	42.53	42.70	42.60
7	38.94	38.96	38.82	38.86	38.92	38.90

Table3-Coconut Fibered Concrete Compressive Strength (MPa)

Fiber(%)	Sample1	Sample2	Sample 3	sample 4	sample5	Average
0	40.76	40.75	40.76	40.85	40.88	40.80
1	42.06	42.03	41.94	42.09	41.88	42.00
2	43.31	43.30	43.26	43.23	43.40	43.30
3	44.61	44.67	44.69	44.71	44.57	44.65
4	45.37	45.44	45.50	45.52	45.42	45.45
5	45.98	46.19	46.04	46.13	46.16	46.10
6	44.16	44.22	44.24	44.26	44.12	44.20
7	42.50	42.52	42.42	42.44	42.37	42.45

Table4-Pinapple Fibered Concrete Compressive Strength (MPa)

Fiber(%)	Sample1	Sample2	Sample3	sample4	sample5	Average
0	40.76	40.75	40.76	40.85	40.88	40.80
1	41.81	41.79	41.83	41.85	41.72	41.80
2	42.56	42.53	42.70	42.60	42.61	42.60
3	43.32	43.39	43.45	43.47	43.37	43.40
4	44.23	44.26	44.14	44.29	44.08	44.20
5	45.40	45.41	45.36	45.33	45.50	45.40
6	45.96	46.02	46.04	46.06	45.92	46.00
7	44.54	44.56	44.65	44.63	44.62	44.60

Table5-Jute Fibered Concrete Compressive Strength (MPa)

Fiber(%)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
0	40.76	40.75	40.76	40.85	40.88	40.80
1	42.15	41.95	42.05	41.70	41.65	41.90
2	43.10	42.90	43.30	43.50	42.20	43.00
3	39.86	39.83	39.74	39.89	39.68	39.80
4	38.61	38.00	38.56	38.53	38.70	38.60
5	37.16	37.22	37.24	37.26	37.12	37.20
6	36.17	36.24	36.30	36.32	36.22	36.25
7	32.43	32.43	32.48	32.41	32.50	32.45

The average value of the test results of five samples/specimen as shown in table6 were given due consideration for obtaining the optimum percentage of fibers for the second stage of investigation.

Table6-Average Value of Concrete Compressive Strength (MPa)

Fiber(%)	Banana	Coconut	Pineapple	Jute
1	43.55	42.00	41.80	41.90
2	46.50	43.30	42.60	43.00
3	49.55	44.65	43.40	39.80
4	52.80	45.45	44.20	38.60
5	49.30	46.10	45.40	37.20
6	42.60	44.20	46.00	36.25
7	38.90	42.45	44.60	32.45

The data were also presented in the form of combined column and line chart keeping in view the importance of the test results in further investigation as already five nos. sample size has been selected to avoid any misleading/incorrect test results at this stage.

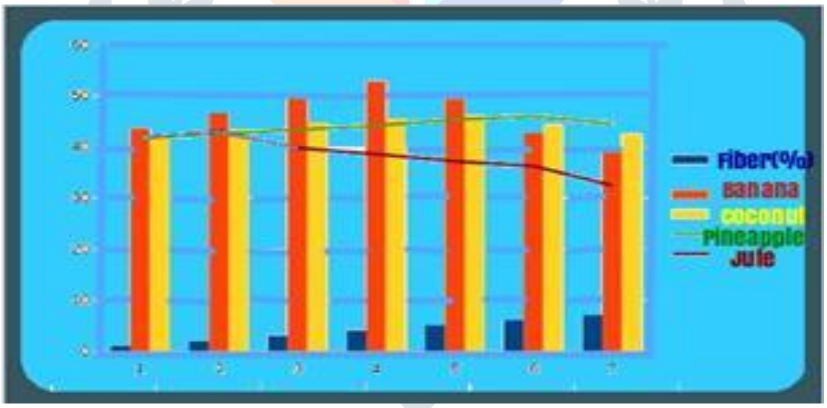

Fig 9- Fiber Percentage Vs Compressive Strength (MPa)

As it is observed from combined column(Banana and Coconut) & line (Pineapple and jute)chart that upto 2percent addition of fiber the compressive strength of three fibers except banana fiber which is slightly higher than coconut fiber up to five percent and after that percentage lower than coconut fiber. However maximum permissible percentage of fiber addition based on compressive strength of banana fiber as 4 percent and coconut fiber as 5 percent were identified. As evident from the line diagram that maximum permissible value of fiber percentage in case of pineapple and jute fiber are 6 ana 2 percent respectively and jute fiber contains the lowest and pineapple fibers highest value of compressive strength at 7percent fiber addition as compared with other fibers. The maximum permissible percentage for the three types of fibers is around five percent except jute fiber which maximum permissible percentage is almost half to one-third as compared with others

4.3- Selection/Performance of Tests

After the identification maximum permissible percentage of fibers on the basis of compressive strength tests performed on the varying percentage of fibers (1-7percent) in the first stage of experimental investigation, in the second stage the slump test ,tensile strength test and flexural strength test on the specimens with identified fiber percentage were carried out for the purpose of comparative / statistical analysis. Keeping in view the importance of maximum permissible percentage identification of samples/specimens size taken as 5 was reduced to three in these tests as the observed values show very little variation and testing becomes a cumbersome and tedious process. The slump test was carried out on fresh concrete whereas cylinders of 150mm diameter and 300mm height for splitting strength and prisms of size 5oommx100mmx100mm for flexural tests were casted/cured and tests were performed as per standard testing procedure.

The mean value of the test results of the slump ,compression, tensile strength and flexural strength tests carried out with three/ five samples of each test without addition of fiber, with addition of banana fibers (4%), coconut fiber (5%),pineapple (6%) and Jute (2%)were taken as shown in table7 for statistical analysis.

Table7-Mean Value of Test Results

S.No.	Particulars	Concrete	Banana	Coconut	Pineapple	Jute
1	Slump **(mm)**	110.00	80.00	110.00	85.00	75.00
2	Compressive Strength**(MPa)**	40.80	52.80	46.10	46.00	43.00
3	Tensile Strength**(MPa)**	04.45	05.90	05.55	04.80	03.60
4	Flexural Srength**(MPa)**	05.50	06.20	06.30	06.40	05.85

4.4- Statistical analysis

As it is observed that there is little variation in flexural strength and tensile strength variation(4.80-5.90) except jute fiber which strength increase as compared with others/concrete lies on minimum standard showing almost little or no scope of its use as fiber in fibered reinforced concrete .This reduction in tensile strength and limited dosing may be due to the longer size fiber jute through the formation of voids in the concrete as reduced workability and balling effect during vibration and casting of specimens/concrete takes place in case of jute fibered concrete. Poor mixing ,chances of segregation of concrete during production almost exists if the jute fibers are used as the result of slump test (lowest value)indicates. Hence only three types of fibers i.e. banana, coconut and pineapple fibers were given due consideration in statistical analysis and the variation measure parameters i.e. difference in value and variation (%)with relative to control parameter i.e. concrete without fiber reinforced concrete were determined / summarized in table8 below:

Table 8-Percentage Variation in Concrete Workability &Strength

Parameter	Banana Fiber(4%)		Coconut Fiber(5%)		Pineapple Fiber(6%)	
	Difference In Value	Variation Percentage	Difference In Value	Variation Percentage	Difference In Value	Variation Percentage
Slump	30.00	27.27	00.00	00.00	25.00	22.72
Compressive Strength	12.00	29.41	05.30	12.99	05.20	12.75
Tensile Strength	02.45	32.58	01.10	24.72	00.35	07.87
Flexural Strength	00.70	12.73	00.80	14.55	00.90	16.36

Slump value of coconut fiber indicates that there is no change in the workability of concrete However variation percentage is around 25 percent less in case of pineapple /banana fibers as compared with concrete shows that less workable concrete mix will be obtained if pineapple/banana fibers are used, Hence in case of Banana/Pinapple fiber certain air training agents or super plasticizers must be used to obtain /improve the workability at the desirable degree..

Though compressive strength increase in between 13-30 percent is evident in all the three types fibered concrete but banana fibered concrete strength increase ,which is almost double of the other two fibers ,provides an extra plus point. As the flexural strength variation in value shows almost similar trends and very little small variation lies between the values/percentage of various fibers, the difference due to use of type of fibers is not distinguishable. As concrete is weaker in tension and fibers are provided for increase the tensile strength of the concrete, Banana fibered concrete has better prospects over others on the ground of tensile strength increase.

V. CONCLUSION

Most of the innovative materials are developed for the substitute/partial replacement of cement and steel as the cement/steel production causes pollution problem and both shares almost 75 percent of the cost of the construction. The use of new innovative materials is based on the following purposes

(I) Enhancing performance i.e. self-healing concrete, permeable concrete and solar roads & materials ,
(II) Use of waste/surplus available materials e.g. sulphur concrete, peat plus shale composites , hydro ceramics and natural fibers etc.
(III) To avoid materials causing environmental pollution problem (Fly ash, thermoplastic carbon fibers and cigarette butts)
(IV) Objective of achieving higher durability and strength i.e. biological concrete, cementless concrete or use of grapheme ,carrot and sugar beets.
(V) Problem solving or specific purpose category-wooden foundation, translucent wood ,light generating cement, breathe bricks etc.

As the behaviour of fibered concrete is primarily responsible on the bond between fiber and surrounding concrete which depends upon the physical characteristics, orientation /surface condition ,chemical composition, length/thickness of fibers used and the bond between fiber and concrete is adjudged by compressive, tensile and flexural strength of concrete, the scope of using fibers under study as partial/full replacement of reinforcement/steel lies in descending order as shown in fig 10 below :

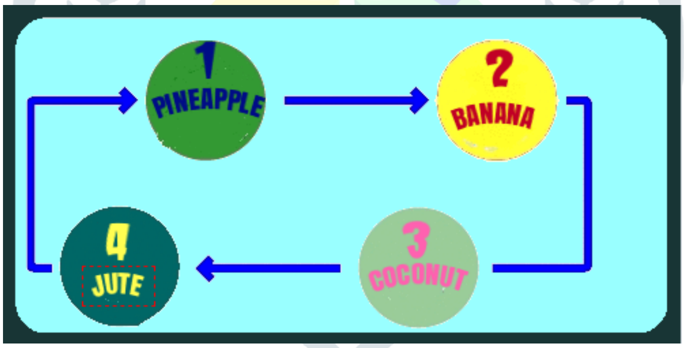

Fig10-Scope of Four Fibers Selected as Concrete Reinforcement

Pineapple fibers on the ground of moisture content & absorption, young's modulus and higher flexural strength deserves for top priority and coconut fiber use at 3rd place on the ground of moisture content &absorption as the coconut fiber shows exceptionally higher value of elongation at break which indicates lower young's modulus and strength. Banana fiber has given priority over coconut fiber and after pineapple fiber on the ground of young's modulus as the chemical treatment in banana fiber is must if used as fiber in fiber reinforced concrete. Though banana fiber compressive strength is higher than pineapple fiber but pineapple fibered concrete has been given priority as the concrete is strong in compression and no compression failure of concrete takes place in practice due to development of carracks and tensile failure before the compression failure stage. Jute fiber has been given last place on the ground of strength/slump tests

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